IDA DOCUMENT D-696

SUMMARY OF THE DoD METAL MATRIX COMPOSITES (MMC) STEERING COMMITTEE MEETING

Hosted by the Institute for Defense Analyses, Alexandria, VA
5-6 October 1989

Michael A. Rigdon
Donald Groves
Editors

November 1989

Prepared for
Defense Advanced Research Projects Agency

IDA

INSTITUTE FOR DEFENSE ANALYSES
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Metal matrix composites (MMC) exhibit a number of properties that make these materials attractive candidates for use in advanced Department of Defense and Strategic Defense Initiative systems. Because of this potential it has been the practice of the various government agencies involved in metal matrix composites research and development to convene meetings periodically in order to discuss the nature and progress of the MMC work being carried on. This report covers the proceedings on such a meeting held on 5-6 October 1989 in which two current aspects--namely, (1) the agency programs and funding and (2) systems transitions/applications--were addressed.

14. SUBJECT TERMS
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Contract MDA 903 84 C 0031
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PREFACE

It has been the practice of the various government agencies involved in metal matrix composite materials (MMC) to have their appropriate representatives meet together periodically to discuss the nature and progress of the MMC work that is being carried on.

Such a forum for discussion was held on 5-6 October 1989. It was hosted by the Institute for Defense Analyses (IDA), Alexandria, VA. The agenda for this particular meeting was designed to cover two generic areas related to current aspects of metal matrix composites efforts. These are: (1) Agency Programs and Funding; (2) Systems Transitions/Applications. The agency programs and funding information, which was presented on the first day (5 October 1989) of the meeting, is summarized in Section A of this document by the inclusion of copies of various self-explanatory viewgraphs shown by the speakers. The data given (6 October 1989) on the topic, Systems Transitions/ Applications, are also summarized in a like manner in Section B herein. Section C contains a listing of the conclusions arrived at and various action items to be appropriately addressed prior to a next meeting of this committee. An Annex covers Focal Area 2 and Focal Area 5 Metal Matrix Composite Developments.

It should be noted that in the interests of timely distribution of this summary no effort has been made to check further with the meeting presenters on the overall accuracy of the aforementioned data. The editors of this document have summarized what they felt to be the most salient parts of the information presented, and have done so primarily by including those copies of the viewgraphs used by the various speakers which reflect this information.

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AGENDA
THURSDAY, 5 OCTOBER 1989,
IDA BOARD ROOM

8:45-9:00	Welcoming Remarks
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9:45-10:30	Navy
10:30-10:45	Coffee Break
10:45-11:30	Air Force
11:30-12:15	DARPA
12:15-1:15	LUNCH
1:15-2:00	SDIO
2:00-2:45	NASP
2:45-3:00	Break
3:00-3:45	NASA
3:45-4:30	DoD/AF Title III Programs (Pitch fibers and MMC Programs
~ 4:30	Adjourn

AGENDA
FRIDAY, 6 OCTOBER 1989,
IDA BOARD ROOM

8:45	Announcements
9:00-9:25	Bill Davis, KETEMA
9:25-9:50	Al Bertram, NSWC
9:50-10:15	V. Johnson/A. Gunderson, WRDC
10:15-10:30	BREAK
10:30-11:00	Marlin Kinna, ONT
11:00-11:25	Frank Traceski, DoD
11:25-11:45	Mike Rigdon, IDA
11:45-12:30	Lunch and Discussion
12:30-1:30	Foreign Company Buy-Outs of US Metal Matrix Composite Companies
1:30-2:30	MMC Information Analysis Center (IAC) Data Base program
2:30-2:45	BREAK
2:45-3:00	The Small Business Innovative Research (SBIR) program in MMCs.
3:00~4:30	Discussion - Committee Discussion led by J. Persh, ODDR&E
~ 4:30	Adjourn

LIST OF ATTENDEES

MMC MEETING
5 October 1989

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SECTION A

AGENCY PROGRAMS AND FUNDING FOR METAL MATRIX COMPOSITES*

SECTION A

AGENCY PROGRAMS AND FUNDING FOR METAL MATRIX COMPOSITES*

ENCLOSURES 1-8

1. Army
2. Navy
3. DARPA
4. USAF
5. SDIO
6. NASP
7. NASA
8. DoD/AF Title III.

* Note: The purpose of this agenda item was to document programmatics and funding (i.e., 6.1, 6.2, 6.3A, and MANTECH 7.8) rather than technical detail. New opportunities and initiatives such as fiber developments, intelligent processing, etc., were also intended to be discussed.

ENCLOSURE 1

U.S. ARMY MMC PROGRAMS AND FUNDING

NOTE: The attached copies of viewgraphs on this subject were presented at the meeting by A. Levitt (USAMTL) and J. Dignam (USAMTL).

METAL MATRIX COMPOSITES

US ARMY
LABORATORY COMMAND

MATERIALS TECHNOLOGY LABORATORY

ACTIVITY	FY89 ($K)	FY90 ($K)	FY91 ($K)	TOTAL ($K)
ARDEFC	970	1,000	1,000	2,970
ARO	504	218	225	947
MICOM	74	55	92	221
MTL	1,790	1,729	1,803	5,322
TOTAL	3,338	3,002	3,120	9,460

MTL FUNDING FOR COMPOSITES

US ARMY LABORATORY COMMAND

MATERIALS TECHNOLOGY LABORATORY

TYPE OF COMPOSITE	FY89	FY90	FY91	TOTAL
ORGANIC MATRIX	12,051	11,276	11,759	35,086
METAL MATRIX	1,790	1,729	1,803	5,322
CERAMIC MATRIX	2,511	2,332	2,432	7,275
CARBON-CARBON	445	626	653	1,724
TOTAL	16,797	15,963	16,647	49,407

TECHNOLOGY TO WIN

MATERIALS TECHNOLOGY LABORATORY

US ARMY
LABORATORY COMMAND

ARO MMC FUNDING

FY	87	88	89	90
$K	182	196	504	218

ESTIMATES OF RESEARCH CONCERNING ORGANIC, CERAMIC & METAL MATRIX COMPOSITES AND CARBON-CARBON 6.2/6.3 - OVERVIEW - FUNDING ($000)

LABORATORY/MSC	ORGANIC MATRIX COMPOSITE			CERAMIC MATRIX COMPOSITE			METAL MATRIX COMPOSITE			CARBON-CARBON		
	FY87	FY88	FY89	FY87	FY88	FY89	FY87	FY88	FY89	FY87	FY88	FY89
MTL	8,930	9,435	9,059	1,814	1,872	1,766	1,583	1,767	1,626	144	130	124
MTL (SDIO)	700	1,500	1,800	-	-	-	250	450	600	300	400	400
BRDEC	755	910	645	-	-	-	85	90	100	-	-	-
TACOM	750	1,350	1,825	-	-	-	-	-	-	-	-	-
BRL	450	400	400	50	50	50	-	-	-	-	-	-
NRDEC	356	525	600	-	-	-	-	-	-	-	-	-
AVSCOM (AEROSTRUCTURES)	998	652	707	-	-	-	-	-	-	-	-	-
TOTAL	12,939	14,772	15,036	1,864	1,922	1,816	1,918	2,307	2,326	444	530	524

US ARMY
LABORATORY COMMAND
MATERIALS TECHNOLOGY LABORATORY

INTERACTION OF ARMY TECHNICAL EFFORTS IN HELICOPTER DRIVE SYSTEMS

6.1

ARO/MTL: CORROSION
FIBER-MATRIX,
INTERACTION,
BONDING

6.2

MTL: MATERIALS
RESEARCH, DEVELOPMENT,
AND EVALUATION
APPLIED TECHNOLOGY LAB:
DESIGN AND ANALYSIS

6.3

MTL - ATD - CONTRACTORS
FABRICATION, TEST OF
SELECTIVELY STIFFENED
HELICOPTER TRANSMISSION
CASE

US ARMY
LABORATORY COMMAND
MATERIALS TECHNOLOGY
LABORATORY

ADVANCED CONCEPTS TECHNOLOGY PROJECT

US ARMY LABORATORY COMMAND

MATERIALS TECHNOLOGY LABORATORY

TITLE: SQUEEZE CASTING METAL MATRIX COMPOSITE FOR M82 BARRETT RIFLE

OBJECTIVE: LIGHTEN RIFLE BY SQUEEZE CASTING METAL MATRIX COMPOSITE (MMC) UPPER RECEIVER

APPROACH: DEVELOP PROCESS TO SQUEEZE CAST MMC

EVALUATE SQUEEZE CAST RECEIVERS

CONTRACTOR: IIT RESEARCH INSTITUTE, CHICAGO IL

FUNDING: $510 K FOR 3 YEARS

ENCLOSURE 2

U.S. NAVY MMC PROGRAMS AND FUNDING

Source: Material presented by S. Fishman (ONR) and John Foltz (NSWC).

ONR METAL MATRIX COMPOSITES
CONTRACT RESEARCH PROGRAM
S.G. FISHMAN, PROGRAM MANAGER

CONTRACTOR	TITLE	FY90 FUNDS	FY91 FUNDS
U. MARYLAND, ARSENAULT	COMPOSITE STRENGTHENING	85000	85000
UCSB, TONY EVANS	METAL/CERAMICINTERFACES	210000	210000
BROWN U., S. NUTT	STRUCTURE OF INTERFACES	90000	90000
NBS, JOHN CAHN	INTERFACE KINETICS	100000	100000
NSWC, DAVE DIVECHA	HI PRESSURE CASTING OF MMC	50000	50000
SoWRI, D. DAVIDSON	FRACTURE/FATIGUE	100000	100000
CORNELL, SASS	INTERFACE STRUCT/ ARCHITECTURE	200000	100000
DREXEL U., KOCZAK	INTERFACIAL RXN KINETICS	90000	90000
MML, M. NATAN	INTERFACIAL REACTIONS	100000	100000
MIT, R. LATANISION	THEORY-ASSIST. INTERF. SYNT.	75000	75000
MIT, ARGON	INTERFACE PROPERTY EVAL.	100000	100000
MIT, MORTENSEN	MMC MATRIX METALLURGY	41000	100000
U. TEXAS, MARCUS	DES. OF MMC INTERFACES	127000	130000
NADC, W. FRAZIER	INTERFACE THERMAL CYCLING	25000	25000
		1,393,000	1,215,000

OVERVIEW OF NAVY 6.2 WORK
IN
METAL MATRIX COMPOSITES

PRESENTED TO
MMC STEERING COMMITTEE

BY JOHN FOLTZ
5 OCTOBER 1989

NAVY 6.2 OVERVIEW
CONTRIBUTING ORGANIZATIONS

NAME (POC)	PROGRAM
NAVAL AIR SYSTEMS COMMAND (I.SHAFFER)	IHPTET
NAVAL AIR DEVELOPMENT CENTER (L.SLOTER)	HYMAT LANDING GEAR
NAVAL SURFACE WARFARE CENTER (W.MESSICK)	TORPEDOES MISSILES SPACE TECH BASE SBIR
OFFICE OF NAVAL TECHMOLOGY (M.KINNA)	SBIR
NAVAL WEAPONS SUPPORT CENTER	ELECTRONICS

USN IHPTET MATERIALS
700°F TITANIUM ALLOY DEVELOPMENT

OBJECTIVE:	DEVELOP AN ELEVATED TEMPERATURE ALUMINUM FOR USE IN ROTATING ENGINE PARTS UP TO 700°F
APPLICATION: TO MMC TECHNOLOGY	THIS EFFORT INCLUDES AN INVESTIGATION OF SPRAY ATOMIZATION OF AN ELEVATED TEMPERATURE ALUMINUM-TITANIUM ALLOY REINFORCED WITH SIC PARTICULATES AT THE UNIVERSITY OF CALIFORNIA
APPROACH:	MODIFY THE STATE-OF-THE-ART RAPIDLY SOLIDIFIED ALLOY COMPOSITIONS TO IMPROVE FRACTURE TOUGHNESS AND TENSILE PROPERTIES
PAYOFF:	ENGINE WEIGHT SAVINGS OF 10-20% ARE PREDICTED FOR SUBSTITUTION OF ALUMINUM FOR TITANIUM IN FAN BLADE APPLICATIONS AND STATIC PARTS INCLUDING ACTUATORS
PERFORMER:	ALLIED-SIGNAL, UNIV. OF CALIFORNIA, NADC
DURATION:	3 YEARS, FY89-FY91
BUDGET:	7.5 MANYEARS

USN IHPTET MATERIALS
1300°F TITANIUM ALLOY DEVELOPMENT

OBJECTIVE:	DEVELOP A NON-BURNING TITANIUM ALLOY FOR HIGH PRESSURE COMPRESSOR APPLICATIONS FROM 1000-1300°F
APPLICATION: TO MMC TECHNOLOGY	POTENTIAL TITANIUM MATRIX FOR CONTINUOUSLY REINFORCED METAL MATRIX COMPOSITES
APPROACH:	MODIFY BETA TITANIUM ALLOY COMPOSITES TO IMPROVE CREEP STRENGTH AND OXIDATION RESISTANCE
PAYOFF:	30-40% WEIGHT REDUCTION FOR SUBSTITUTION OF TITANIUM FOR NICKEL ALLOYS IN COMPRESSOR AND EXHAUST APPLICATIONS
PERFORMER:	PRATT AND WHITNEY
DURATION:	4 YEARS, FY89-FY92
BUDGET:	11 MANYEARS

USN IHPTET MATERIALS
GAMMA TITANIUM ALUMINIDE

OBJECTIVE: DEVELOP GAMMA TITANIUM ALUMINIDE ALLOYS FOR USE IN STATIC STRUCTURES AND ROTATING ENGINE PARTS UP TO 1800°F

APPLICATION: TO MMC TECHNOLOGY
- ALLOY COMPOSITIONS DEVELOPED MAY BE SUITABLE FOR COMPOSITE MATRICES
- CONCEPTS INCLUDE DISPERSION STRENGTHENING OF THE GAMMA MATRICES FOR HIGHER TEMPERATURE STRENGTH AND RESISTANCE TO CRACKING AT LOW TEMPERATURES

APPROACH: MODIFY CURRENT ALLOY COMPOSITIONS AND PROCESSING TO IMPROVE PRODUCABILITY, FRACTURE TOUGHNESS,TENSILE AND CREEP PROPS

PAYOFF:
- 50% REDUCTION IN PART DENSITY vs. NICKEL ALLOYS LEADING TO INCREASED ENGINE T/W
- INCREASED ROTOR TIP SPEED CAPABILITY FOR IMPROVED EFFICIENCY

PERFORMER: TBD

DURATION: 4 YEARS, FY90-FY93

BUDGET: 23 MANYEARS

USN IHPTET MATERIALS
METAL MATRIX COMPOSITE (MMC) JOINING

OBJECTIVE:	DEVELOP JOINING TECHNOLOGY FOR BLADED ROTORS AND ROTOR DRUMS TO COMBINE TITANIUM ALLOYS, INTERMETALLICS AND METAL MATRIX COMPOSITES
APPLICATION: TO MMC TECHNOLOGY	ENABLING TECHNOLOGY FOR FABRICATION OF MULTIPLE ALLOY PARTS INCLUDING REINFORCED MATERIALS
APPROACH:	INVESTIGATE JOINING METHODS THAT DO NOT DAMAGE THE MMC REINFORCEMENT AND REINFORCEMENT/MATRIX INTERFACE
PAYOFF:	INCREASED DESIGN FLEXIBILITY TO INCORPORATE LOW DENSITY MATERIALS INTO ENGINE COMPRESSORS AND TURBINES FOR SIGNIFICANT WEIGHT REDUCTIONS AND INCREASED PERFORMANCE
PERFORMER:	TBD
DURATION:	4 YEARS, FY90-FY93
BUDGET:	10 MANYEARS

ALUMINIDE METAL MATRIX COMPOSITES

(CONTRACTOR; GARRETT, CONTRACT NO. N62269-86-C-0248)

- OBJECTIVE
  - DEVELOP ALUMINIDE MMC SYSTEM FOR 1400 DEGREES F APPLICATION

- APPROACH
  - SELECT TITANIUM ALUMINIDE MATRIX AND CERAMIC FIBER-REINFORCED MATERIALS
  - ESTABLISH FIBER/MATRIX REACTION KINETICS
  - DEVELOP MODEL FOR MECHANICAL PROPERTY PREDICTION
  - VALIDATE MODEL BY MECHANICAL PROPERTY TESTING OF COMPOSITE SYSTEM

- ACCOMPLISHMENTS
  - MATERIAL PROCUREMENT (COMPLETE)
  - REACTION STUDIES (75% COMPLETE)
  - MODELLING (IN PROGRESS)
  - TEST VERIFICATION (IN PROGRESS)

- TRANSITIONS
  - ADVANCED GAS TURBINE ENGINE COMPRESSOR DISKS
  - ADVANCED GAS TURBINE ENGINE LOW PRESSURE TURBINE DISKS

STUDY ON TITANIUM ALUMINIDE XD COMPOSITE

NADC

- **OBJECTIVE**
  - IDENTIFY METALLURGICAL FEATURES
  - ESTABLISH OXIDATION MECHANISM
  - CHARACTERIZE FATIGUE BEHAVIOR

- **ACCOMPLISHMENT/TRANSITION**
  - IDENTIFICATION OF MICROSTRUCTURE, CONSTITUENT PHASES, AND DISLOCATION AND TWIN SUBSTRUCTURES
  - CLARIFICATION OF OXIDATION KINETICS
  - UNDERSTANDING OF FATIGUE BEHAVIOR UNDER TENSION-TENSION AND COMPRESSION-COMPRESSION LOADING
  - MANUFACTURING TECHNOLOGY PROGRAM FOR AERO-VEHICLE COMPONENTS
  - DEVELOPMENT OF NIOBIUM ALUMINIDE AND ITS COMPOSITES

- **APPROACH**
  - SPECIMEN MATERIAL: (Ti-45 at % Al) + 7 vol % TiB_2
  - METALLURGICAL EXAMINATION BY OPTICAL AND ELECTRON MICROSCOPY
  - OXIDATION TREATMENT AND ITS PRODUCT EXAMINATION
  - FATIGUE TEST, CRACK GROWTH ANALYSIS, AND FRACTOGRAPH EVALUATION

- **INTERACTION**
  - NAVAL RESEARCH LABORATORY
  - MARTIN MARIETTA LABORATORIES

REFRACTORY-BASED XD INTERMETALLICS

(CONTRACTOR; MARTIN MARIETTA, CONTRACT NO. N62269-89-C-0233)

- OBJECTIVE
  - DEVELOP OXIDATION-RESISTANT REFRACTORY BASED INTERMETALLIC COMPOSITES FOR 2800 DEGREES F APPLICATION

- APPROACH
  - EMPLOY IN-SITU FORMATION VIA XD TECHNOLOGY TO PRODUCE INGOT-BASED COMPOSITES
  - DEVELOP CONTAINERLESS PLASMA CONVERSION DEPOSITION PROCESS

- ACCOMPLISHMENTS
  - 50 COMPOSITE SYSTEMS PRODUCED
    - BORIDE, CARBIDE, NITRIDE, SILICIDE REINFORCEMENTS
    - NIOBIUM, TANTALUM BASED MATRICE
  - PLASMA CONVERSION DEMONSTRATE IN NIOBIUM/ALUMINIUM SYSTEM

- TRANSITIONS
  - IHPTET
  - HYPERVELOCITY MISSILES

MMC UNDERWATER WEAPONS

STATUS AND PLANS

MK 46 LIGHTWEIGHT TORPEDO SHELLS

* SUCCESSFULLY TESTED AT OPERATIONAL PRESSURE
* SUCCESSFULLY TESTED FOR BENDING MOMENT LOAD
* VIBRATION TESTS IN PROGRESS (NOSC)
  - 1,300,000 CYCLES AT 7 KSI, 30 HZ COMPLETED
* PLAN TO FABRICATE 3 SHORT FUEL TANKS FOR T&E BY NOSC

MK 50 LIGHTWEIGHT TORPEDO ARRAY PLATE

* SUCCESSFULLY TESTED FOR WATER IMPACT SHOCK (NSWC HYDROBALLISTIC TANK)
* PLAN TO STUDY WARHEAD PERFORMANCE

MATERIAL IS SIC/AL

MMC UNDERWATER WEAPONS

STATUS AND PLANS

MK 48 HEAVYWEIGHT TORPEDO ARRAY PLATE
* TWO UNITS MADE AND OPERATING
* SUCCESSFULLY TESTED FOR PASSIVE NOISE
* POWERED SELF-NOISE TESTS IN PROGRESS (DABOB BAY & AUTEC)
* LEVERAGE PROVIDED BY NUSC
  - TEST VEHICLES & FUNDING
* PLAN IS TO FABRICATE ONE PIECE NOSE/ARRAY FOR EVALUATION BY NUSC

TORPEDO ENGINE COMPONENTS
* *MK 46* PISTON UPGRADE
  - PLAN TO TEST ALL-MMC & HYBRID PISTONS
* *MK 48* ADCAP COMBUSTION CHAMBER UPGRADE
  - HIGH THERMAL CONDUCTIVITY MMC NEEDED

MATERIAL IS SIC/AL

ADVANCED MISSILE MATERIALS

PROJECT STATUS

SIC/AL DORSAL FINS
* PROGRAM COMPLETED
* TECHNICAL GOALS MET, 50% COST SAVING
* FINAL REPORT IN PREPARATION

REINFORCED TITANIUM MMC
* BORON CARBIDE & NIOBIUM CARBIDE PARTICLES DIDN'T WORK (POROSITY & REACTION EVIDENT)
* YTTERBIA FLAKES - TESTING UNDER WAY, RESULTS ENCOURAGING

XD TITANIUM ALUMINIDE FLIGHT CONTROL SURFACES
* NEW START

THERMAL MANAGEMENT
* NEW START

<u>HIGH TEMPERATURE RESPONSE OF SIC/AL</u>

PROJECT FY90+FY91 funding = $865K

ADVANCED MISSILE MATERIALS
SM-2, BLK II, MR DORSAL FIN

REQUIREMENT
* FORM, FIT AND FUNCTION WITH EXISTING GR/PI FINS WITH NO INCREASE IN WEIGHT

CONTRACTOR
* GENERAL DYNAMICS/POMONA (SYSTEM PRIME) DWA, RMI, LMI, BARSON MACHINE, EDM SPECIALTIES

INVESTMENT
* NAVY - $300K
* GENERAL DYNAMICS - ?

PAYOFF
* 50% DECREASE IN COST, MMC EXTRUSION VS LABOR INTENSIVE LAYUP OF GR/PI
* MINIMAL SCRAP RATE WITH MMC

ADVANCED MISSILE MATERIALS
SM-2, BLK II, MR DORSAL FIN

ACCOMPLISHMENTS

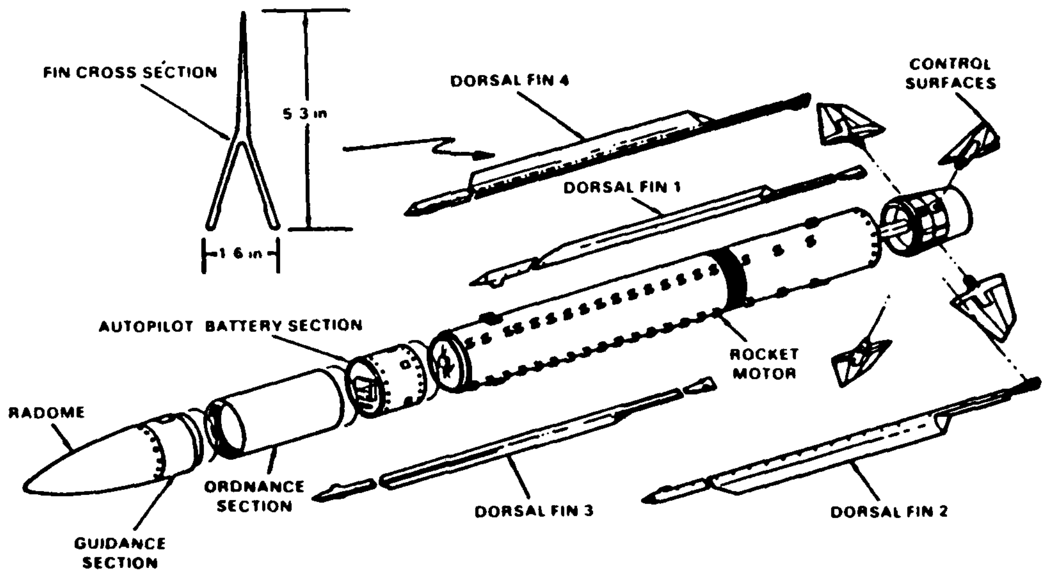
* SIX PROOF TESTED PRODUCTION QUALITY DORSAL FINS FABRICATED, READY FOR FLIGHT

* FABRICATION TECHNIQUES REFINED
    - EXTRUSION DIES, LUBRICANTS
    - HEAT TREATING
    - STRETCH STRAIGHTENING
    - WELDING
    - EDM
    - DIAMOND DRILLS

* BRIEFED PMS422

ADVANCED MISSILE MATERIALS

SM-2, BLK II, MR SiC/ALUMINUM DORSAL FIN



- REQUIREMENTS
  - FORM, FIT, AND FUNCTION WITH EXISTING SM-2, BLK II, MR DORSAL
  - NO INCREASE IN WEIGHT
- PAYOFF
  - REDUCED COST OF ASSEMBLY (≈50%)

NSWC SPACE PROGRAM

STATUS AND PLANS - GR/AL TRUSS

GR/AL MATERIALS QUALIFICATION (LMSC)
* SPECIFICATION FOR GR/AL TUBES DEVELOPED
* B4C/AL END FITTINGS FABRICATED
* SUCCESSFULLY BUILT & TESTED 11 FT 3-BAY TRUSS
* SECOND TRUSS ASSEMBLED
* PLAN TO TEST SECOND TRUSS IN EARLY FY90

JOINING TECHNOLOGY FOR TRUSS MATERIALS
* LOW TEMPERATURE SOLID-STATE BONDING METHOD DEVELOPED FOR TRUSS MATERIALS (SPARTA)
* PLAN TO INVESTIGATE BRAZING TECHNIQUES (AEROSPACE)

LASER SURVIVABILITY OF TRUSS (MSC)
* SELECTED REPRESENTATIVE SPACECRAFT & COMPONENT
* ANALYTICAL METHODS DEVELOPED
* HIGH TEMPERATURE DATA BASE NOW BEING GATHERED

NSWC MMC PROGRAM

STATUS AND PLANS

DISCONTINUOUS MMC DEVELOPMENT
* MATERIALS ORDERED FOR T&E (NSWC)
* DIMENSIONALLY STABLE SIC/MG DEV. (DRAPER)

CENTRIFUGAL CASTING OF SIC/AL
* FEASIBILITY SHOWN ON 4 IN DIAMETER TUBES
* PLAN TO FAB. 12 IN DIAMETER TUBES (WESTINGHOUSE)

THERMAL MANAGEMENT OF SPACECRAFT
* PLANNED NEW START

FY90 FUNDS ▪ $700K

ADVANCED COMPOSITES FOR SATELLITE AND MISSILE APPLICATIONS

HIGH SPECIFIC STIFFNESS MAGNESIUM COMPOSITES
POWDER METALLURGY PROCESSED AT ACMC

- ZK60A-T5/ 20 v/o SiC (WHISKER) EXTRUDED
- ZK60A-T5/ 20 v/o SiC (WHISKER) FORGED

HIGH SPECIFIC STIFFNESS MAGNESIUM COMPOSITES
CASTINGS PROCESSED AT FMI

- ZK61A-T6/ 25 TO 35 v/o SiC (PARTICULATE)
- ZK61A-T6/ 25 TO 35 v/o B4C (PARTICULATE)

HIGH THERMAL CONDUCTIVITY ALUMINUM COMPOSITES

- 6101-T6/ 25 TO 30 v/o SiC (PARTICULATE)
- 6101-T6/ 25 TO 30 v/o AlN (PARTICULATE)

JBC091289

NAVY SBIR PROGRAMS

NSWC

PERFORMER	TITLE	FY/PHASE
NETCO; AML	CRYOGENIC BEHAVIOR OF MMCS	86/2
SYNTERIALS	HIGH TEMP. ZERO CTE MATERIALS	88/1
TRA	GR/AL BY LMI	89/1
SOLOHILL	COATED REINFORCEMENTS FOR NIAL COMPOSITES	89/1
GORHAM MATL'S INST	FAB. OF DENSE NI ALUMINIDES	89/1

NAVY SBIR PROGRAMS

NSSC/ONT

PERFORMER	TITLE	FY/PHASE
ROI	THERMAL MANAGEMENT	86/2
MSC	GR/CU MODELING	86/2
SPARTA	GR/CU APPLICATIONS	86/2
DWA	THERMAL EXPANSION CONTROL	86/2
DWA	FAB. OF PTM COMPOSITES	86/2
MCI	NEAR NET SHAPE CASTING	86/2
MSC	MODELING OF COMPONENTS	86/2
ROI; RCI	COMPOSITES IN ELECTRONIC DEVICES	87/2; 87/1
TTI; SPARTA; NAMCO	THERMAL MANAGEMENT OF HIGH HEATING LOADS	88/1 (ALL)
RCI	HIGH CHAR YIELD POLYMER MATRIX COMPOSITES	88/1

ENCLOSURE 3

DARPA MMC PROGRAMS AND FUNDING

Source: Material presented by Ben Wilcox, DARPA

DARPA
METAL MATRIX COMPOSITES

	FY 88	FY89
Pratt & Whitney	1700K	1636K
UCSB (URI)	1500K	1600K
RPI (URI)	800	800
MIT	-	170
USC	94	67
MM DENVER	100	-
ROCKETDYNE	162	-
MM BALTIMORE	1200	303
NRL	300	95
GE		500
MM BALTIMORE	-	591
	-----	-----
	~~4,156K~~ 5856K	~~4,126K~~ 5,762

DARPA

FIBERS AND FIBER COATINGS

	FY88	FY89
Dow Corning	$3,000K	$1,000K
Allied Signal	100	100
General Atomics	--	460
UCSB	--	449
Pratt & Whitney	--	196
	$3,100K	$2,205K

TABLE 2-2
CANDIDATE COATING MATERIALS

		Coating	
Matrix	Fiber	Debond	Protective
γ-TiAl	TiB_2	Ti	Y_2O_3
	Al_2O_3	Nb-Ti	Al_2O_3
			IR
Nb-based intermetallic	W	Y_2O_3	
	Al_2O_3	$MoSi_2$	
Al_2O_3	Al_2O_3	Nb, NiAl	Al_2O_3
	SiC	BN	SiC
AlN	Al_2O_3	BN	SiC
SiC	SiC	$MoSi_2$, Ti_5Si_3	SiC or Si_3N_4
	C	Nb_5Si	SiC
		Self	
Si_3N_4	SiC	$MoSi_2$	
	Si_3N_4	$MoSi_2$	
	C	Self	

(Adapted from UCSB)

ENCLOSURE 4

U.S. AIR FORCE MMC PROGRAMS AND FUNDING

Source: A. Rosenstein (AFOSR/NE), William Koop (WRDC),
A. Gunderson (WRDC)*, V. Johnson (WRDC)

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* Additional WRDC material on MMC development is provided in the Annex (see p. 195).

SUMMARY CHART OF AF MMC FUNDING

SUMMARY CHART of AF MMC FUNDING								
Fiscal Yr.	87	88	89	90	91	92	93	94
Totals								
6.1	0	260	519	519	519	519	519	
6.2	1246	4522	4759	5979	4615	3148	2575	2685
6.3	5867	5116	3491	4236	2331	3484	3065	
7.8				547	3600	5600	4960	
NASP	9879	43417	36895	6866	4700			
SDI	1150	2200	2380	3766	4333	5106	5333	5833
TITLE III	13000	13000	7100	5000	5000	5000		

SUMMARY CHART-AL

SUMMARY CHARTof AF MMC FUNDING

	FISCAL YEAR	87	88	89	90	91	92	93	94
6.1	MLLN IN-HOUSE	0	250	250	250	250	250	250	
	MECH OF MMC	0	170	170	170	170	170	170	
6.1	MLLS IN-HOUSE	0	99	99	99	99	99	99	
6.1	ML TOTAL	0	260	519	519	519	519	519	
6.2									
	FA2 IN-HOUSE	0	50	96	200	275	300	400	500
	FA2-3	744	961	677	1085	400	450	400	400
	FA2-4				217	400	325	200	
	FA2-5				200	437		125	285
	FA5-1	330	223	155	325	660	600	650	600
	FA5-2	0	250	265	460	760	760	800	900
;.2 TOTAL ML		1074	1484	1193	2487	2172	2435	2575	2685
		6.2	PO	170	2558	3155	2741	1473	713
		6.2	FI	2	480	411	751	970	
6.2 TOTAL		1246	4522	4759	5979	4615	3148	2575	2685

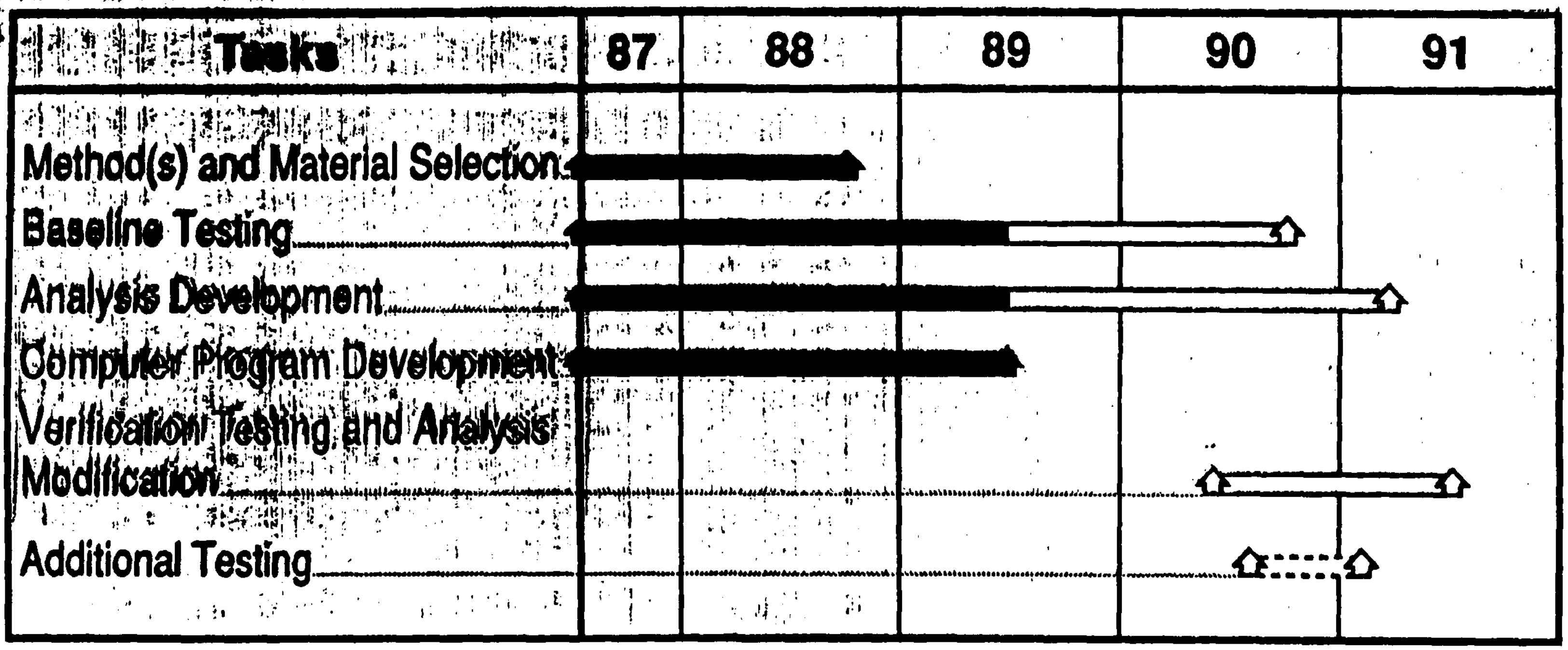
SUMMARY CHART-AL

		87	88	89	90	91	92	93	94
6.3	FI	5867	4028	2737	4236	2331	3484	3065	
	P.O.		1088	754					
6.3	TOTAL	5867	5116	3491	4236	2331	3484	3065	
7.8	MT				547	3600	5600	4960	
NASP		9879	43417	36895	6866	4700			
SDI	DEV.	1150	2200	1640	1100	900	1200	1500	1500
	DEMO.			740	2666	3433	3906	3833	4333
SDI	TOTAL	1150	2200	2380	3766	4333	5106	5333	5833
TITLE	III	13000	13000	7100	5000	5000	5000		

METAL MATRIX COMPOSITE STRUCTURES

		FY89	FY90	FY91	FY92	FY93
MATERIAL DEVELOPMENT						
- HIGH TEMP FIBER DEV	(7)		0.500	0.590		
STRUCTURAL BEHAVIOR						
- BIG BUY	(1)	0.025				
- THERMOMECH LOADING	(2)	0.160	0.200	0.151		
- IN-HOUSE TESTING	(3+4)	0.251	0.251	0.229		
STRUCTURAL DEMONSTRATION						
- ADV FTR VERT STAB	(8)	1.840	1.709			
- F-15 ADV MET STRUCT	(9)	0.115	0.364			
- COMPOSITE DISK VALID	(10+11)	0.594	0.300	0.573	0.300	0.457
- HIGH TEMP COMPR ROTOR	(12)		0.325	0.600	1.300	0.600
- ARALL APPLS STUDY	(17)		0.432			
- ARALL FLIGHT DEMOS	(18+19)	0.079	0.030			
- ADV ALUM MMC STRUCT	(13)			0.063	0.575	0.750
- DAMPING & MMC SPACE STRUCT	(14+15+16)	0.109	1.076	1.095	1.309	1.258
- DAMPING IN COMPOSITES	(6)	0.030				
- AMASS	(5)		0.670	1.000	1.333	0.333
- OPT PRECISION SPACE STRUCT	(20)		0.067	0.100	0.100	

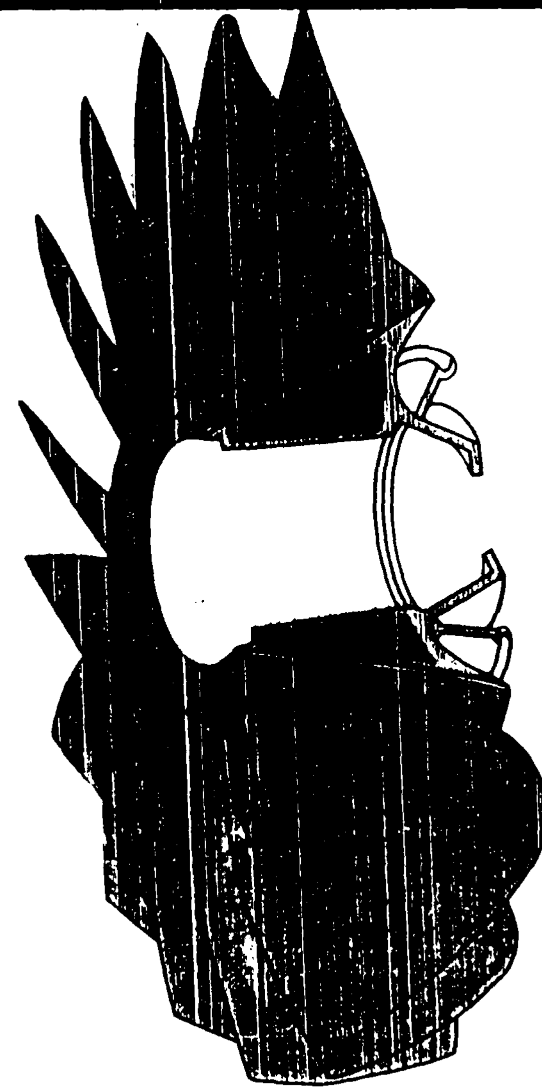
Program Schedule



GP93-0307-25-D


PROGRAM
SiC$_W$ / Al
SiC$_F$ / Al

PT-03



Objectives

- Conduct Design Studies, Establish Feasibility, and Design Near Term and Far Term MMC Disk Rotors
- Detailed Design, Fabricate and Demonstrate a Near Term MMC Disk Rotor
- Update Designs for Near Term and Far Term MMC Disk Rotors

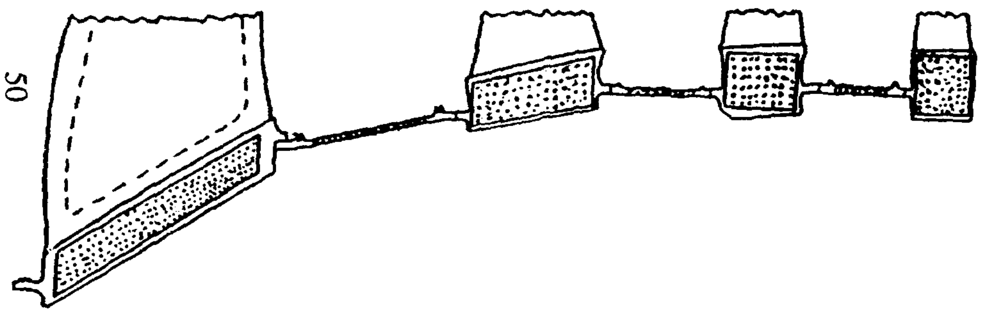
Payoffs

- 30% Weight Savings with a Near Term MMC Disk
- > 50% Weight Savings with a Far Term MMC Rotor
- Engine Demonstration of an MMC Disk Rotor

HI-TEMP COMPRESSOR ROTOR

PE: 63211F
PROJ: 486U
WU: 02XX

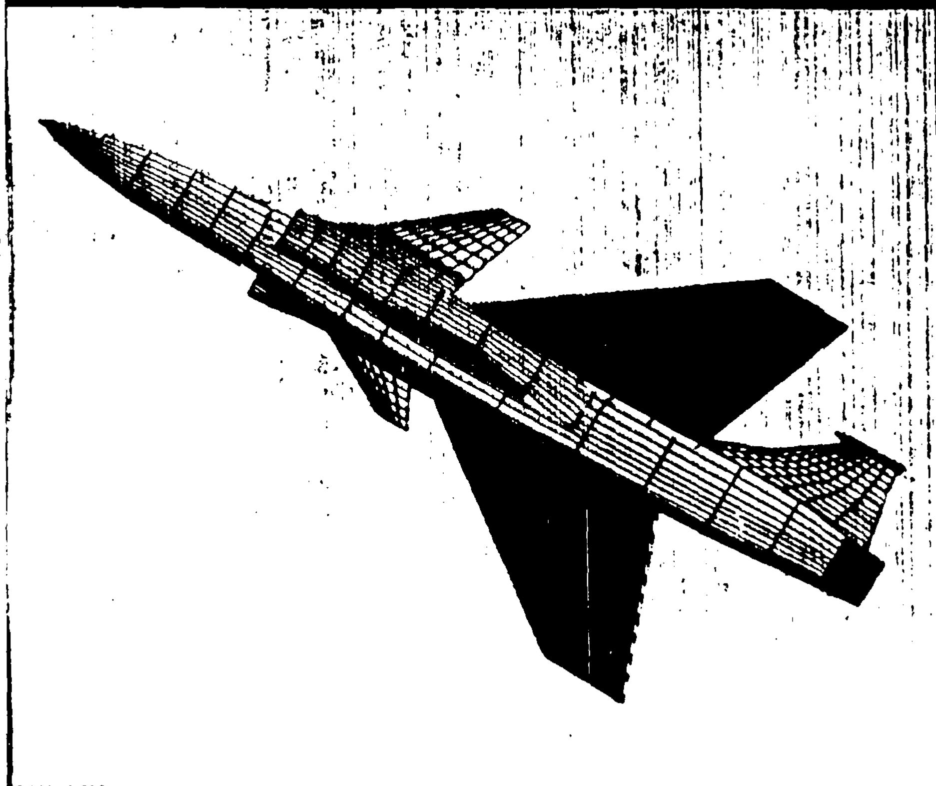
ADVANCED METALLIC STRUCTURES ADP



- SUPER PLASTIC FORMING
- DIFFUSION BONDING
- HOLLOW BLADING
- BLADED RINGS
- POWDER METALLURGY
- ADV CERAMIC FIBERS
- HI-TEMP Ti ALLOYS
- NEW MMC CONSOLIDATION
- MMC NDI/NDE
- CHEM-MILLING

TO DESIGN, FABRICATE, AND TEST AN HPTET COMPRESSION SYSTEM WITH +150^{o}F COMPRESSOR EXIT TEMPERATURE CAPABILITY

... TECHNOLOGY
... MMC STRUCTURE



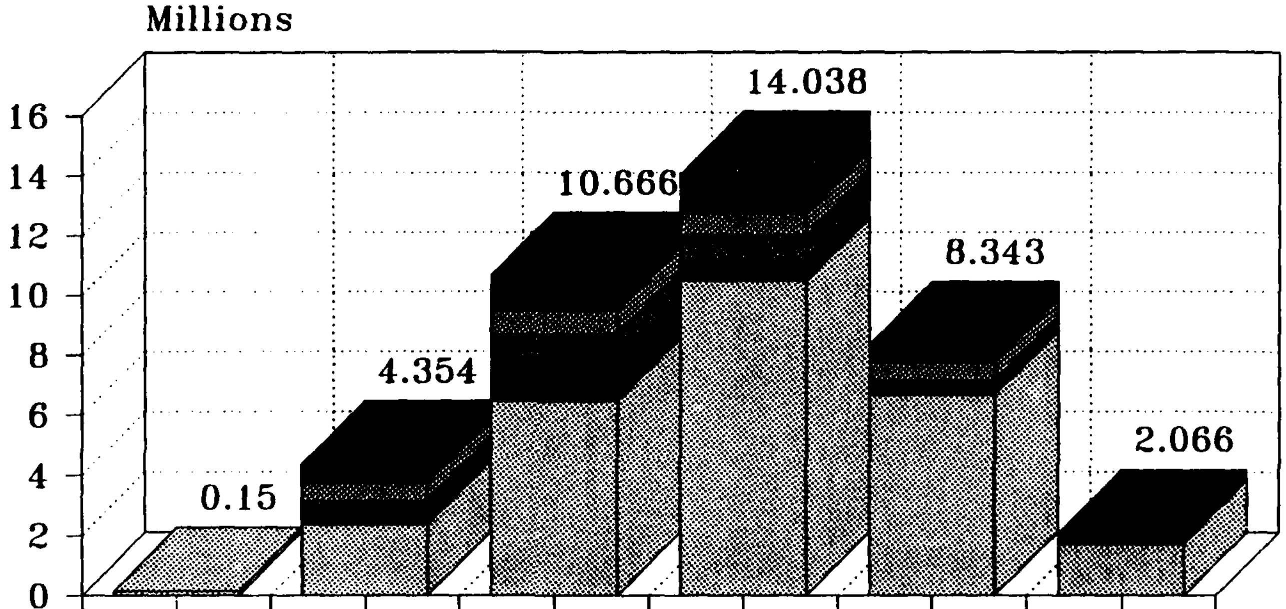
OBJECTIVES:

- DEMONSTRATE 15% WEIGHT REDUCTION AND 50% COST REDUCTION OVER CONVENTIONAL TITANIUM STRUCTURES
- DESIGN, FABRICATE, AND TEST SELECTED DEMONSTRATION COMPONENTS
- SCALE-UP TO FULL COMPONENT SIZE

Overview

- MMC Technology Areas
  - Disks
  - Static Structures
  - Fan Blades
  - Adv. Fiber / Coatings
  - Prediction
- HPTET PRDA II MMC Awards
- Concerns

HPTET PRDA II Funding



	89	90	91	92	93	94
FIBAA		0.623	1.19	1.3	0.6	0.243
ML		0.593	0.79	0.715	0.591	
POOC		0.147	0.763	0.829	0.011	
POSL		0.645	1.471	0.719	0.485	0.124
POT	0.15	2.346	6.452	10.475	6.656	1.699

Concerns

- SiC Fiber Non-Availability Issue Remains High Priority
  - MMC Fabrication Industry Remains Stifled
- Adv. SiC Fiber Needed For IHPTET Phase II
  - Better Compatibility with Matrix
  - CTE Mismatch <20%
  - 3-8 mil Dia.
- Need Vehicle for MMC Data Transfer
  - Need More Action From MMCIAC
  - Standard Data Record for All MMC Programs
  - DID to Forward Data to MMCIAC

SUMMARY

- MMC Disks Remain a High Priority ($ 12.9 M)
- Feasibility of MMC Static Structures is Underway ($ 5.9 M)
- Next Generation of Hollow MMC Fan Blades Identified ($ .5 M)
- Advanced Fibers / Coatings for MMCs Starting ($ 2.2 M)
- MMC Prediction is Newest Emphasis Area ($ 4.2 M)

SUMMARY

- MMC Disks Remain a High Priority ($ 12.9 M)
- Feasibility of MMC Static Structures is Underway ($ 5.9 M)
- Next Generation of Hollow MMC Fan Blades Identified ($ .5 M)
- Advanced Fibers / Coatings for MMCs Starting ($ 2.2 M)
- MMC Prediction is Newest Emphasis Area ($ 4.2 M)

AFOSR PROGRAM

- AIMED AT HIGH TEMPERATURE INTERMETALLIC MATRIX AND REFRACTORY ALLOY MATRIX COMPOSITES
  - ONGOING PROGRAMS ON TI AND NI ALUMINIDES
  - NEW PROGRAMS ON NB ALUMINDES AND $MOSI_2$

- LONG TERM EFFORT TO GAIN FUNDAMENTAL UNDER-STANDING
  - SYNTHESIS AND PROCESSING SCIENCE
  - INTERFACE PHENOMENA
  - MECHANICAL PROPERTIES/MECHANISMS

- FUNDING
  - FY 89 - $1000K
  - FY 90 OUTLOOK - 5-10% INCREASE IN EFFORT

ENCLOSURE 5

SDIO MMC PROGRAMS AND FUNDING

Source: S. Fishman (ONR)

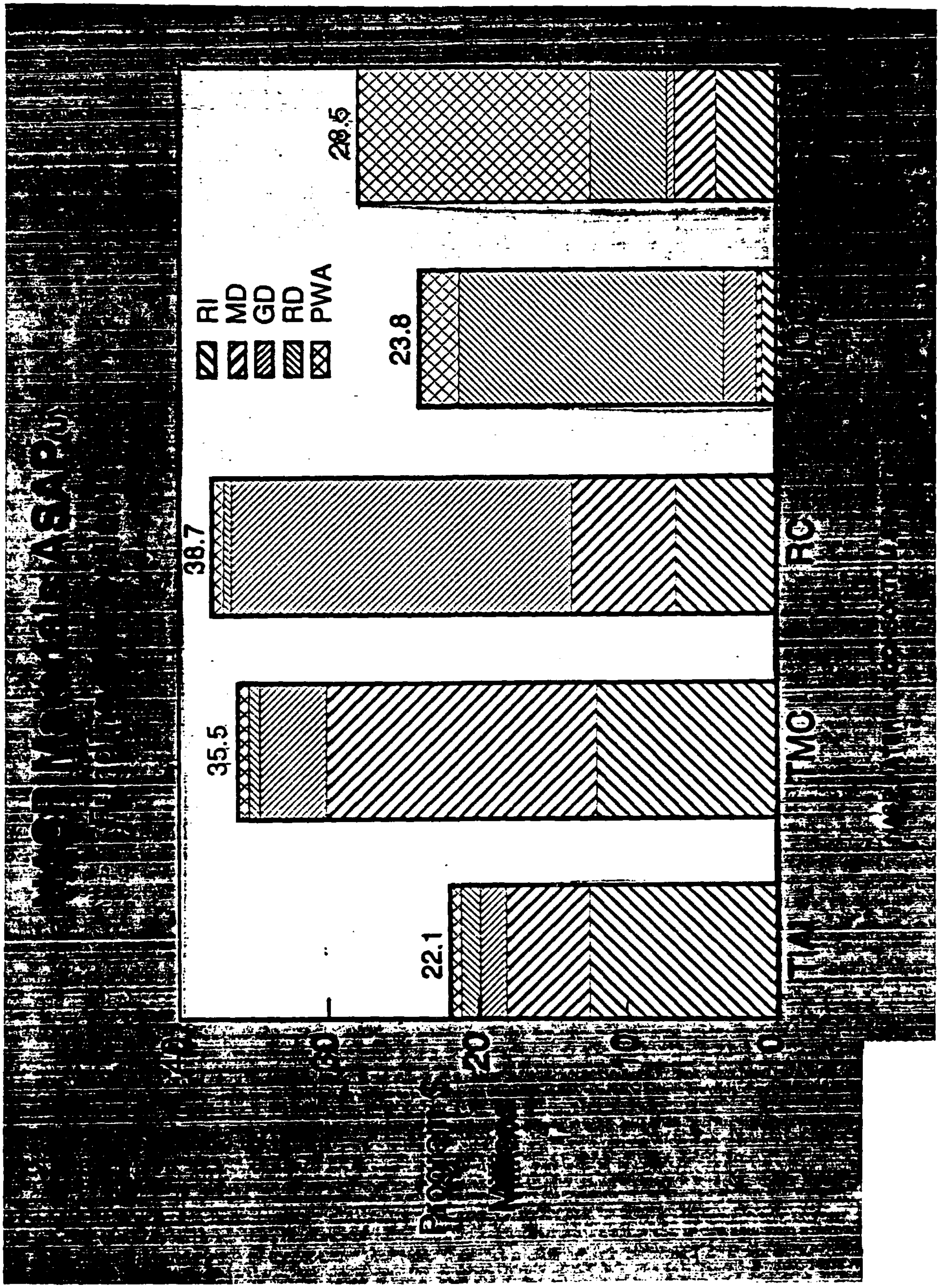
SDIO/IST ADVANCED COMPOSITES PROGRAM

Metal Matrix Composites	Start Date	End Date	FY87	FY88	FY89	FY90	FY91
Dr. Jim Cornie MIT	01 Jul 85	31 Jan 90	1200	750	600	500	300
Dr. Glen Edwards Col Mines	01 May 85	30 Apr 91	110	90	40	90	90
Dr. Mohan Misra Martin Marietta Aerospace	15 Sep 85	31 Dec 90	180	180	88	200	200
Ceramic Matrix Composites							
Dr. Karl Prewo UTRC	01 May 85	28 Feb 91	180	180	370	370	370
Dr. Steve Freiman NBS	01 Aug 86	14 Jun 90	130	110	60	0	0
Dr. Rick Laine U of Wash	07 Jun 86	31 Mar 90	170	119	90	200	200
Dr. Kay Paciorek Ultrasystems		30 Jun 90	180	150	50	0	0
UCSB, F. Lange						200	200
Intermetallic Composites							
Dr. P. Kumar Martin Mar.	17 Jun 85	16 Dec 90	300	150	62	150	150
Dr. Vince Nardone UTRC	15 Jun 87	14 Sep 90	300	300	460	460	460
Dr. Said Nourbakhsh NY Poly	01 Sep 86	30 Sep 89	170	170	100	200	200
Dr. D. Lashmore NBS	01 Jun 86	30 Sep 90	0	50	75	150	150
Characterization/Modeling							
Dr. H. Wadley NBS	01 Apr 85	30 Sep 87	150	0	0	0	0
Dr. M. Rosen Johns Hopkins	08 Dec 86	07 Dec 88	75	75	20	0	0
Dr. G. Dvorak RPI	01 Jul 85	31 Jan 91	155	107	94	100	100
Dr. J. Duffy Brown	15 Jun 85	31 Jan 90	150	124	0	0	0
Dr. J. Awerbuch Drexel	01 Jul 85	30 Sep 88	110	0	0	0	0
Dr. S. Wang U of Ill.	10 Apr 86	01 Apr 90	260	167	150	70	70
Dr. J. Epstein EG&G	23 Apr 86	30 Sep 88	90	60	0	0	0
Dr. Rizzo U. of KY	04 Jun 86	30 Sep 88	90	50	50	70	70
Dr. A. Kobayoshi U. of Wash.	01 Apr 87	31 Jan 90	92	92	70	90	90
Dr. Adler, Ohio State U.			0	0	157	150	150
					2500	3000	

ENCLOSURE 6

NASP MMC PROGRAMS AND FUNDING

Source: F. Boensch, AFSC



RI
MD
GD
RD
PWA
22.1
35.5
38.7
23.8
28.5
TMC
RC
0
20

NASP

CONSORTIUM DIRECTORATE

MATERIALS ASAP

- BASIC CONTRACT TASKS
  - MASTER PLANNING DOCUMENT
  - DEFINITION OF REQUIREMENTS
  - PROCESS IDENTIFICATION
  - MATERIAL CHARACTERIZATION
  - FABRICATION EFFECTS
  - SCALE-UP
  - COMPONENT TEST (OPTIONAL)
  - TECHNOLOGY TRANSFER
  - ASSOCIATE CONTRACTOR AGREEMENT
- EXISTING CONTRACTUAL VEHICLE

NASP METAL MATRIX
TITANIUM MATRIX COMPOSITES

TASK	FY88	FY89	FY90	FY91	TOTAL
1,2,8,9	470	1472	1698	439	4079
3	685	8744	1575	0	11004
4	179	2274	4783	311	7547
5	17	3681	5811	444	9953
6	0	656	2091	129	2876
TOTAL	1351	16827	15958	1323	35469

$K

NASP METAL MATRIX
HIGH SPECIFIC CREEP STRENGTH MAT'L

TASK	FY88	FY89	FY90	FY91	TOTAL
1,2,8,9	398	848	1047	354	2647
3	2307	10799	4169	10	17285
4	50	817	1121	21	2009
5	1	1146	2681	66	3894
6	0	835	1874	4	2713
TOTAL	2756	14445	10892	455	28548

$K

NASP METAL MATRIX

HIGH CONDUCTIVITY COMPOSITES

TASK	FY88	FY89	FY90	FY91	TOTAL
1,2,8,9	290	669	726	76	1761
3	168	2568	664	0	3400
4	32	968	1897	0	2897
5	0	1248	1181	0	2429
6	0	42	1387	12	1441
TOTAL	490	5495	5855	88	11928

$K

NASP METAL MATRIX

OTHER MMC

TASK	FY87	FY88	FY89	FY90	FY91	TOTAL
AMMC	1250	2000	500	500	1000	5250
TiAl COMP	4000	4650	3710	4500	3700	20560
TOTAL	5250	6650	4210	5000	4700	25810

$K

ENCLOSURE 7

NASA MMC PROGRAMS AND FUNDING

Source: William Brewer, NASA Langley, H. Gray, NASA Lewis

METAL AND INTERMETALLIC MATRIX COMPOSITES
FUNDING SUMMARY

	ORGANIZATION	FY87 ($K)	FY88 ($K)	FY89 ($K)	FY90 ($K)
AEROPROPULSION APPLICATIONS					
• HITEMP - FIBERS, COMPOSITE MECHANICS, INTERFACES	PENN STATE	---	500	500	500
• CONTINUOUS CVD FIBER (TiB_2)	SUNY	---	87	98	122
• HIGH CTE FIBER (Nb_2Be_{17})	TEXTRON	---	---	150	---
• COMPLIANT/DIFFUSION COATING ON SiC	TEXTRON	---	---	150	---
• EXOTHERMIC REACTION SYNTHESIS OF IMC	U. MICHIGAN	---	---	75	7
• RESIDUAL STRESS MEASUREMENTS	GE	---	---	90	90
• XD - PROCESSED $TiAl_3$	MARTIN MARIETTA	---	---	119	130
• PVD OF CrB_2 FIBERS	P&W - W. PALM	---	---	80	80
• TBD		---	---	---	
• TBD	TBD	---	---	---	~200
• STRUCTURE-PROPERTY RELATIONS IN $NbAl_3$	U. FLORIDA	---	50	45	45
• IMPROVED DUCTILITY IN NiAl	PENN STATE	---	50	50	50
• DEFORMATION MECHANISMS IN $NbAl_3$	U. TENN	---	50	50	50
• FIBER/MATRIX (NiAl, FeAl) REACTIONS	OHIO STATE	---	---	45	35
* IN-HOUSE RESEARCH - IMC's (FeAl, SiC/Ti_3Al, $NbAl_3$, SiC/Ti-15-3, NiAl, FIBERS)	LeRC	~500	~2000	2189	2050
* IN-HOUSE RESEARCH - COATINGS FOR IMC's	LeRC	---	~200	340	340
		~500	~2900	3981	3705

METAL MATRIX COMPOSITES

	ORGANIZATION	FY85	FY86	$K FY87	FY88	FY89	FY90
SPACE POWER APPLICATIONS							
● Mo-HfC WIRE DEVELOPMENT	METADYNE	50	495	---	---	---	---
● DIFFUSION BARRIER ON W WIRE	U. TEXAS	---	---	---	60	63	60
* IN-HOUSE RESEARCH (W/Nb-1Zr, Gr/Cu)	LeRC	100	200	600	300	300	300
		150	695	600	360	363	360
SPACE PROPULSION APPLICATIONS							
● W/SUPERALLOY SSME BLADE DEVELOPMENT	ROCKETDYNE	---	100	150	---	20	---
● W-Re-HfC WIRE DEVELOPMENT	AMAX	60	264	340	364	425	261
* IN-HOUSE RESEARCH (W/Cu, W/SUPERALLOYS)	LeRC	---	---	---	150	40	70
		60	364	490	514	485	341
		210	1059	1590	3774	4829	4406

* IN-HOUSE RESEARCH DOES NOT INCLUDE C. S. SALARIES

METAL MATRIX COMPOSITES RESEARCH
LANGLEY RESEARCH CENTER

AERONAUTICS

- INTERMEDIATE TEMPERATURE STRUCTURES
  - DISCONTINUOUSLY REINFORCED AL
- *HIGH TEMPERATURE STRUCTURES*
  - CONTINUOUSLY REINFORCED TI, TI_xAL
  - BERYLLIDES

SPACE

- PRECISION STRUCTURES
  - GRAPHITE REINFORCED AL, MG

ADVANCED METAL MATRIX COMPOSITES FOR AIRFRAME AND SPACE STRUCTURES

LANGLEY EMPHASIS

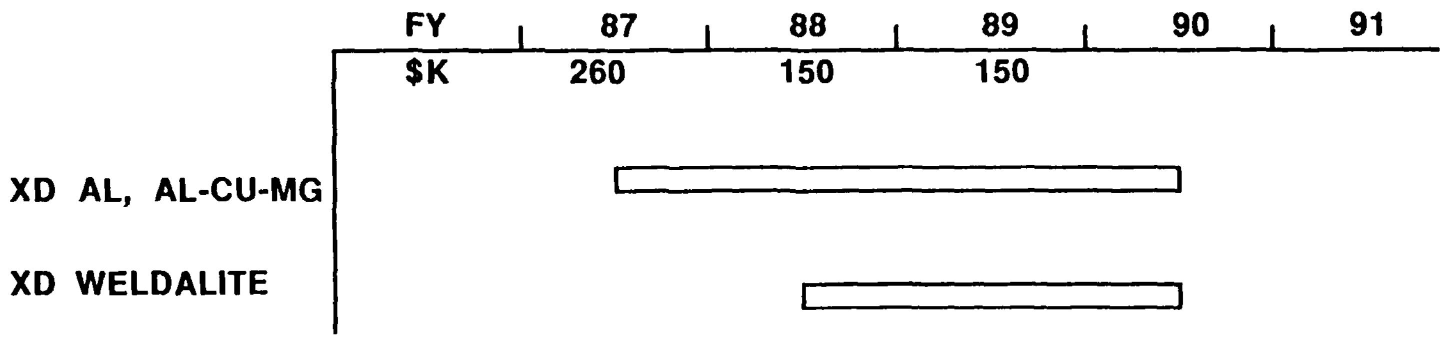
- THIN GAGES
- LIGHTWEIGHT MATERIALS
- LIGHTLY LOADED STRUCTURES

HSR, GENERIC HYPERSONICS, NASP, TAV, STS, OTV, SPACE STRUCTURES

MECHANISMS OF DISPERSION STRENGTHENING AND FRACTURE IN AL-BASED XD ALLOYS

(MARTIN MARIETTA, BALTIMORE LABS)

- TIB_2 /AL, AL-CU-MG
  - REINFORCEMENT SIZE, VOLUME FRACTION, MATRIX DEFORMATION, HEAT TREATMENT EFFECTS ON STRENGTH AND TOUGHNESS
- WELDALITE
  - FEASIBILITY, PROPERTIES OF XD WELDALITE



LANGLEY RESEARCH CENTER

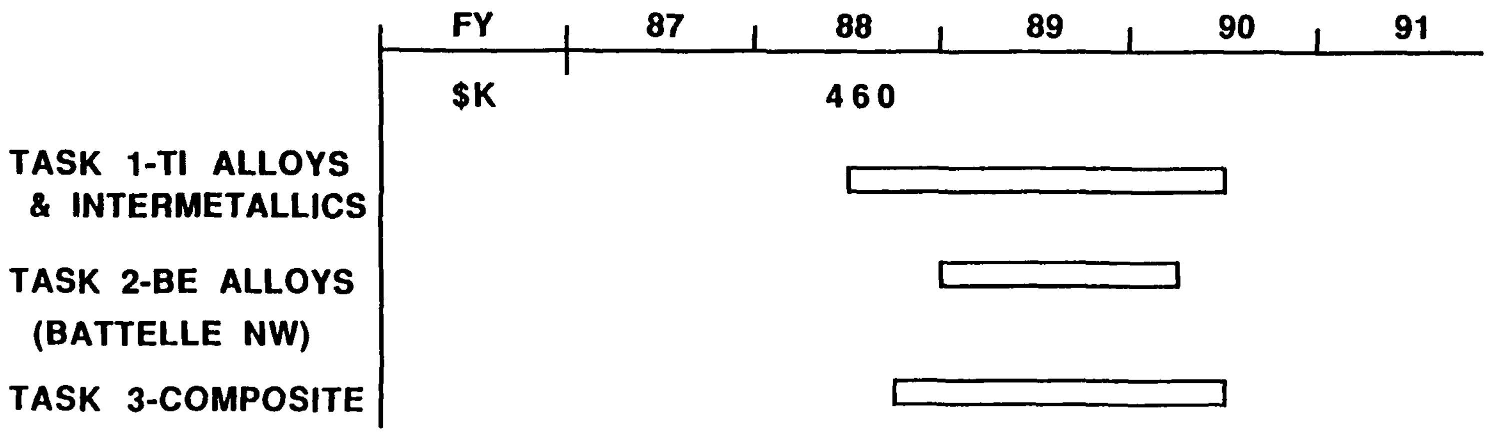
WDB 10/89

FABRICATION OF FOIL GAGE SHEET MATERIAL BY PHYSICAL VAPOR DEPOSITION

(PRATT & WHITNEY)
(BATTELLE NW)

- DEVELOP PVD TECHNIQUES TO FABRICATE FOIL GAGE MATERIALS OF TI, TI_X AL, AND BERYLLIUM

- APPLY TECHNIQUES TO FABRICATE CONTINUOUSLY REINFORCED TI AND TI_X AL COMPOSITES



LANGLEY RESEARCH CENTER

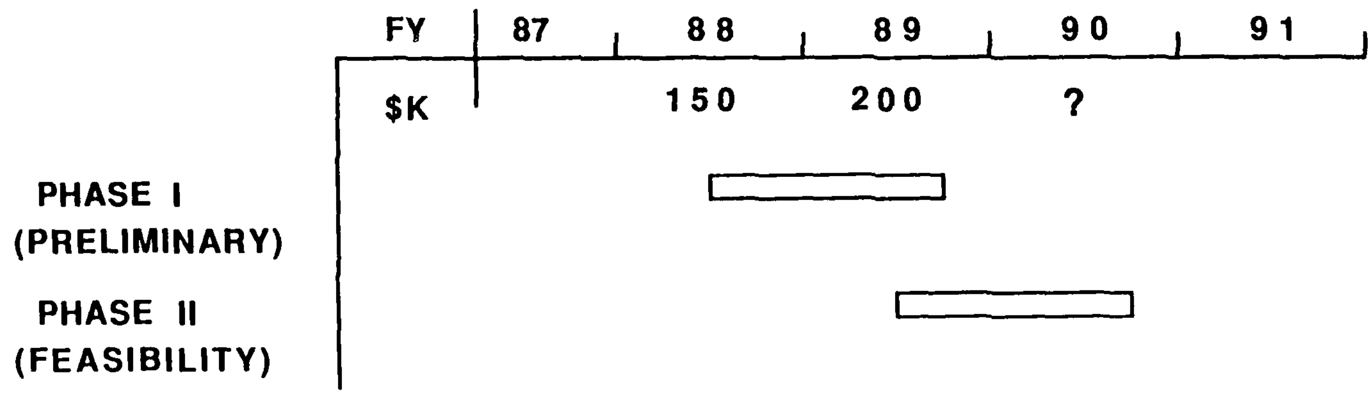
WDB 10/80

DIRECT CONSOLIDATION OF TITANIUM ALUMINIDE MATRIX COMPOSITES USING BLENDED POWDER

(ROCKWELL SCIENCE CENTER)

- <u>AVOID FIBER DAMAGE</u>
  - BLENDED α-2 AND γ Ti_xAl POWDERS
  - LIQUID PHASE CONSOLIDATION AIDS
  - LOW CONSOLIDATION PRESSURE

- <u>MINIMIZE DELETERIOUS INTERACTIONS</u>
  - MULTILAYER METALLIC COATINGS ON FIBERS



LANGLEY RESEARCH CENTER

WDB 10/89

AMMC - 2 DEVELOPMENT

(LOCKHEED AERONAUTICAL SYSTEMS)

MATERIALS ARE CLASSIFIED

- FIBER/COATING/MATRIX COMPATIBILITY
- PREFORM DEVELPOPMENT
  - DIRECT POWDER
  - PLASMA SPRAY
  - COLD SPRAY
- CONSOLIDATION
  - VACUUM HOT PRESS
  - HOT ISOSTATIC PRESS
- TEST/EVALUATION
  - FIBERS
  - COATED FIBERS
  - COMPOSITES
- THEORETICAL ANALYSIS
- SCALE-UP ASSESSMENT

	FY	87	88	89	90	91
	$K	1250	2000	500	?	
AMMC-2 DEVELOP						

LANGLEY RESEARCH CENTER

WDB 10/89

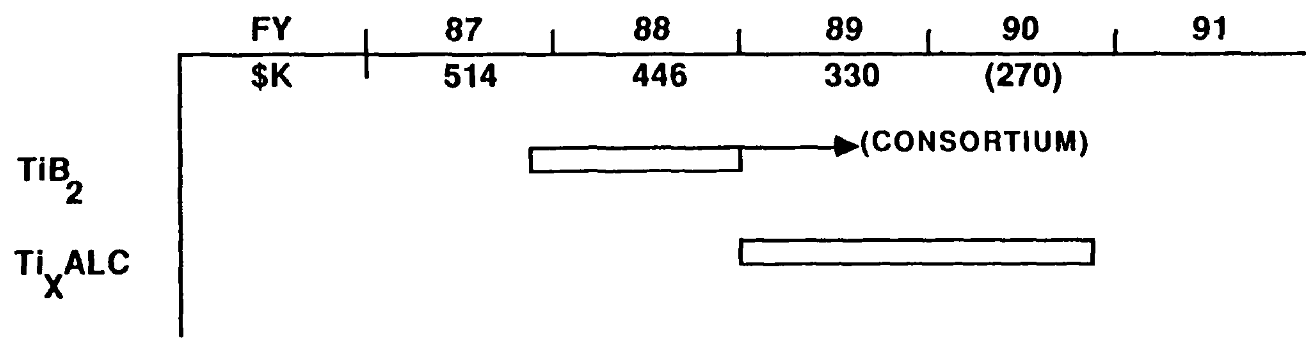
DEVELOPMENT OF HIGH TEMPERATURE FIBERS BY CHEMICAL VAPOR DEPOSITION

(TEXTRON SPECIALTY MATERIALS)

- TiB_2 FIBER DEVELOPMENT
- Ti_XALC FIBER DEVELOPMENT
  - Ti_2ALC, Ti_3ALC

TARGETS

- 3 MIL DIA FIBER
- > 300 KSI STRENGTH



LANGLEY RESEARCH CENTER

WDB 10/89

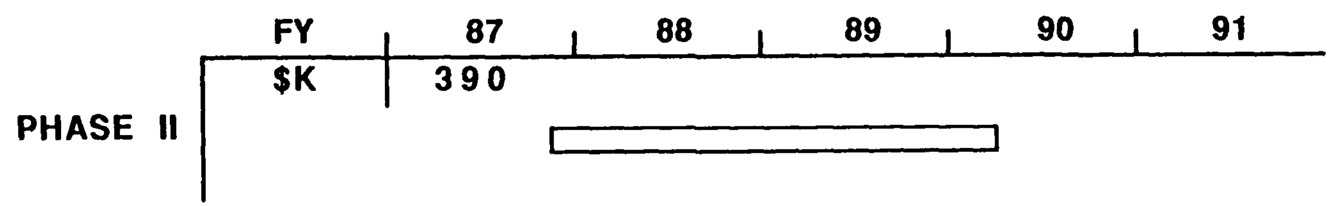
IMPROVED FRACTURE TOUGHNESS IN DISCONTINUOUSLY REINFORCED METAL MATRIX COMPOSITES

(MSNW, SBIR PHASE II)

- THERMOCHEMICAL MODELING
  - PREDICT STABLE SYSTEMS

2XXX AL	SIC_P
AL-FE-MO	TIC_P
AL_3TI	$(SI, TI)C_P$

- COMPOSITE FABRICATION
  - MECHANICAL ALLOYING
- POST-FABRICATION PROCESSING
  - THERMOMECHANICAL



LANGLEY RESEARCH CENTER

WDB 10/89

SYNTHESIS OF HIGH PURITY BERYLLIDES

(NSMW, SBIR)

PHASE I

- DEFINE PROCESS CHEMISTRY TO DIRECTLY PRODUCE HIGH PURITY REFRACTORY BERYLLIDES - POWDER, FOIL, BULK
- ANALYTICALLY DETERMINE THE COMPATIBILIY/STABILITY OF VARIOUS POTENTIAL BERYLLIDE COMPOSITE SYSTEMS

PHASE II

- FABRICATE, TEST, ANALYZE BERYLLIDES/COMPOSITES USING PROCESSES/CHEMISTRY/MATERIALS DEFINED IN PHASE I

	FY	89	90	91
	$K	4 9		
PHASE I				
PHASE II			?	

LANGLEY RESEARCH CENTER

WDB 10/89

LANGLEY SPONSORED CONTRACTS - MMC

FUNDING SUMMARY

	FY 87	FY 88	FY 89	FY 90	FY 91	TOTAL $K
MARTIN - BALT	260	150	150			560
PRATT & WHITNEY (BATTELLE, NW)		460				460
ROCKWELL SCI CEN.*		150	200	(175)		350*
TEXTRON*	514	446	330	(270)		1290*
LOCKHEED*	1250	2000	500	(320)		3750*
MSNW (SBIR I, II)	50	400				450
MSNW (SBIR I)			50			50
TOTAL $K	2074	3606	1230	(765)		6910

* NASP FUNDED

LANGLEY RESEARCH CENTER

WDB 10/89

LANGLEY SPONSORED GRANTS - MMC

CLEMSON
- FRACTURE CRITERIA FOR SIC_W /Al COMPOSITES
  - MATERIALS ANALYSIS
  - MECHANICS, TESTING

RPI
- THERMO-VISCO-PLASTIC MODELING OF MMC
- RESIDUAL STRESS MODELING

WASHINGTON
- VISCOPLASTIC CHARACTERIZATION OF SIC/TI-15-3

UVA
- REACTION KINETICS/PROPERTIES OF SIC/TI
  - TI 1100, B21S, TIAl
  - SCS-6, 9, 10

UVA
- MULTI-STRESS EFFECTS ON MMC BEHAVIOR

VPI
- X-RAY DETERMINATION OF RESIDUAL STRESSES IN MMC
  - FABRICATION EFFECTS
  - POST-FAB PROCESSING

LANGLEY SPONSORED GRANTS - MMC

FUNDING SUMMARY

	FY 87	FY 88	FY 89	FY 90	FY 91	TOTAL $K
CLEMSON	60 K	80 K	50 K	50 K		240
RPI		25 K	25 K	25 K		75
U. OF WASH.			50 K	50 K		100
UVA			45 K	55 K		100
UVA			35 K	35 K		70
VPI				55 K		55
TOTAL $K	60	105	205	270		640

LANGLEY RESEARCH CENTER

WDB 10/89

LANGLEY IN-HOUSE MMC ACTIVITIES

Ti, Ti_x Al MATIRX

- FABRICATION (CONVENTIONAL)
- TEST/EVALUATION (TO 2000 °F)
- CONSTITUENT COMPATIBILITY

- JOINING PRACTICE
  - ENHANCED DIFFUSION BONDING
  - SANDWICH PANEL FABRICATION

- FATIGUE & FRACTURE/DAMAGE TOLERANCE

- MODEL DEVELOPMENT/LIFE PREDICTION

LANGLEY RESEARCH CENTER

WDB 10/89

LANGLEY IN-HOUSE MMC ACTIVITIES

SiC_p , SiC_w /Al

DECREASING EMPHASIS

- ALLOY CHEMISTRY
- INTERFACE STRUCTURE
- THERMO-MECHANICAL PROCESSING
- TOUGHNESS/DURABILITY
- MECHANICS/MODELING

LANGLEY IN-HOUSE MMC ACTIVITIES

GR/Al , MG/Al

P100/6061 "BIG BUY"

P100/AZ91, ZK60, QH21

- THERMAL CYCLING/RESIDUAL PROPERTIES
- CTE MEASUREMENTS
- PROCESSING FOR MINIMUM HYSTERESIS

LANGLEY RESEARCH CENTER

WDB 10/89

LANGLEY MMC FUNDING SUMMARY

	FY 89	FY 90
IN-HOUSE	350	300
GRANTS	205	270
CONTRACTS	1230	765
TOTAL $K	1785	1335
MANPOWER CIVIL SERV. & NPS	5 PMY	5 PMY

NEW OPPORTUNITIES

- FIBER DEVELOPMENT - CRITICAL TO MMC SUCCESS
- Be ALLOYS/BERLLIDES - COULD BE IMPORTANT
- FASTENING/JOINING - NEEDS ATTENTION
- ALTERNATE FABRICATION - SHOULD BE PURSUED
- THIN GAGES - IMPORTANT FOR LIGHT WEIGHT

ENCLOSURE 8

DOD/AF TITLE III

Mr. Bill Johnson (DPA) briefly discussed two current Title III contracts. One of these is for ~$22 million with DWA as the prime contractor and ALCOA as the subcontractor. The other has ACMC as prime contractor and Allied as the subcontractor, and is for ~$11 million. Both involve the production of high- and moderate-strength discontinuous reinforced aluminum matrix composites. A third $8 million contract with Amoco is for *high-modulus carbon fibers*.

SECTION B

METAL MATRIX COMPOSITES--
SYSTEMS TRANSITIONS/APPLICATIONS

SECTION B

METAL MATRIX COMPOSITES--
SYSTEMS TRANSITIONS/APPLICATIONS

Note: In this section the data given by the presenters are summarized primarily by the attached copies of the viewgraphs which were shown on the second day (6 October 1989) of the DoD Metal Matrix Composites Steering Committee meeting. The presenters and their topics were as follows:

Presenter	Topic
William Davis, KETEMA	"SDS Spacecraft Materials Evaluation Program"
S. Knight, SA-ALC	"Advanced Metals and Ceramics TAPM"
A. Bertram, NSWC	"Reproducible Gr/Al Materials for SDI Applications"
V. Johnson, WRDC	"Advanced Metallic Structures"
F. Traceski, DoD	"Specification Developments for Metal Matrix Composites"
D. Crafts, Treasury*	"Foreign Buyouts"
William McNamara, Kaman	"The MMC Numerical Data Base"
T. Pojeta, OSD-R&AT, Tempo	"DoD Materials and Structures SBIR"
J. Foltz, NSWC	"Advanced Composites for the Trident Guidance System" and Lightweight Torpedo Shells"
M. Rigdon, IDA	"The Metal Matrix Composites Question"

* No viewgraphs.

SDS SPACECRAFT MATERIALS EVALUATION PROGRAM

William E. Davis of the Composite Materials Division of KETEMA Inc., in discussing the Spacecraft Materials Evaluation Program, covered the technical issues involved, the key consideration for advanced materials, the data and information needs for spacecraft designers, and the program objectives. Also, his firm has recently evolved a Materials Selection Guide or handbook. This information is summarized in the attached copies of the viewgraphs utilized in Mr. Davis' presentation.

KETEMA CMD

TECHNICAL ISSUES

- SDI SYSTEMS MUST CONDUCT VERY DIFFICULT MISSION OPERATIONS
- MANY NEW TECHNOLOGIES ARE NEEDED TO ENHANCE SDS PERFORMANCE CAPABILITIES
- MATERIALS AND STRUCTURES TECHNOLOGIES CAN HAVE A SIGNIFICANT IMPACT ON SDI SYSTEMS
    - SURVIVABILITY
    - PERFORMANCE
    - COST
- SPACECRAFT DESIGNERS REQUIRE DATA AND INFORMATION ON ADVANCED MATERIALS IN ORDER FOR THEM TO BE CONSIDERED FOR APPLICATION TO SPACECRAFT SYSTEMS

KETEMA CMD

KEY CONSIDERATIONS FOR ADVANCED MATERIALS

1. **PRODUCT FORM:**
   - WHAT SHAPES CAN BE MADE WITH THE MATERIAL?
   - WHAT PRODUCT SOURCES, FABRICATION AND PROCESS SPECIFICATIONS FOR BUILT-UP STRUCTURE GEOMETRIC ACCURACY EXIST?
   - HOW REPRODUCIBLE IS THE PRODUCT, WHAT ARE THE LEAD TIMES, WHAT IS THE COST/LB.?
   - ARE JOINING METHODS ESTABLISHED?

2. **MECHANICS**
   - DO ANALYTICAL PREDICTION TOOLS EXIST?
   - DO ANALYTICAL PREDICTIONS CORRELATE WITH TEST DATA?
   - DO THE MATERIALS/STRUCTURAL COMPONENTS EXHIBIT PREDICTABLE BEHAVIOR?
   - CAN THE STRUCTURAL INTEGRITY BE DETEMINED BY STRESS ANALYSIS WITH APPROPRIATE TESTING?

3. **NON-DESTRUCTIVE EVALUATION**
   - DO QUALITY CONTROL PROCEDURES EXIST?
   - HOW PROVEN ARE THE QC METHODS?
   - DO AUTOMATED PROCESSES EXIST? CAN EXISTING PROCESSES BE AUTOMATED?

4. **MANUFACTURING TECHNOLOGY**
   - HOW CAN COSTS BE REDUCED?
   - CAN MANUFACTURING QUALITY OR REPRODUCIBILITY BE IMPROVED?
   - DO CURRENT PROCESSES LEND THEMSELVES TO AUTOMATED PRODUCTION?
   - CAN LARGER QUANTITY MANUFACTURING BE HANDLED?
   - CAN LARGER OR SMALLER PARTS BE MADE?

5. **ENGINEERING DATA**
   - WHAT TEST DATA EXISTS ON SMALL COUPONS OR BUILT-UP STRUCTURES?
   - DOES THE FOLLOWING DESIGN DATA EXIST? (MECHANICAL, THERMAL, ENVIRONMENTAL, THREAT)
   - WHAT NONLINEAR EFFECTS ARE CHARACTERIZED?
   - IN WHAT VALIDATED QUANTITIES?

6. **CONSTITUENT MATERIALS**
   - WHAT IS THE COST?
   - WHAT SOURCES EXIST?
   - WHAT IS THE VOLUME OF MATERIAL THAT CAN BE PURCHASED?
   - WHAT IS THE LEAD TIME?
   - DO THEY REQUIRE ANY SPECIAL STORAGE OR HANDLING FACILITIES/EQUIPMENT?

KETEMA
CMD

DATA AND INFORMATION NEEDS FOR SPACECRAFT DESIGNERS

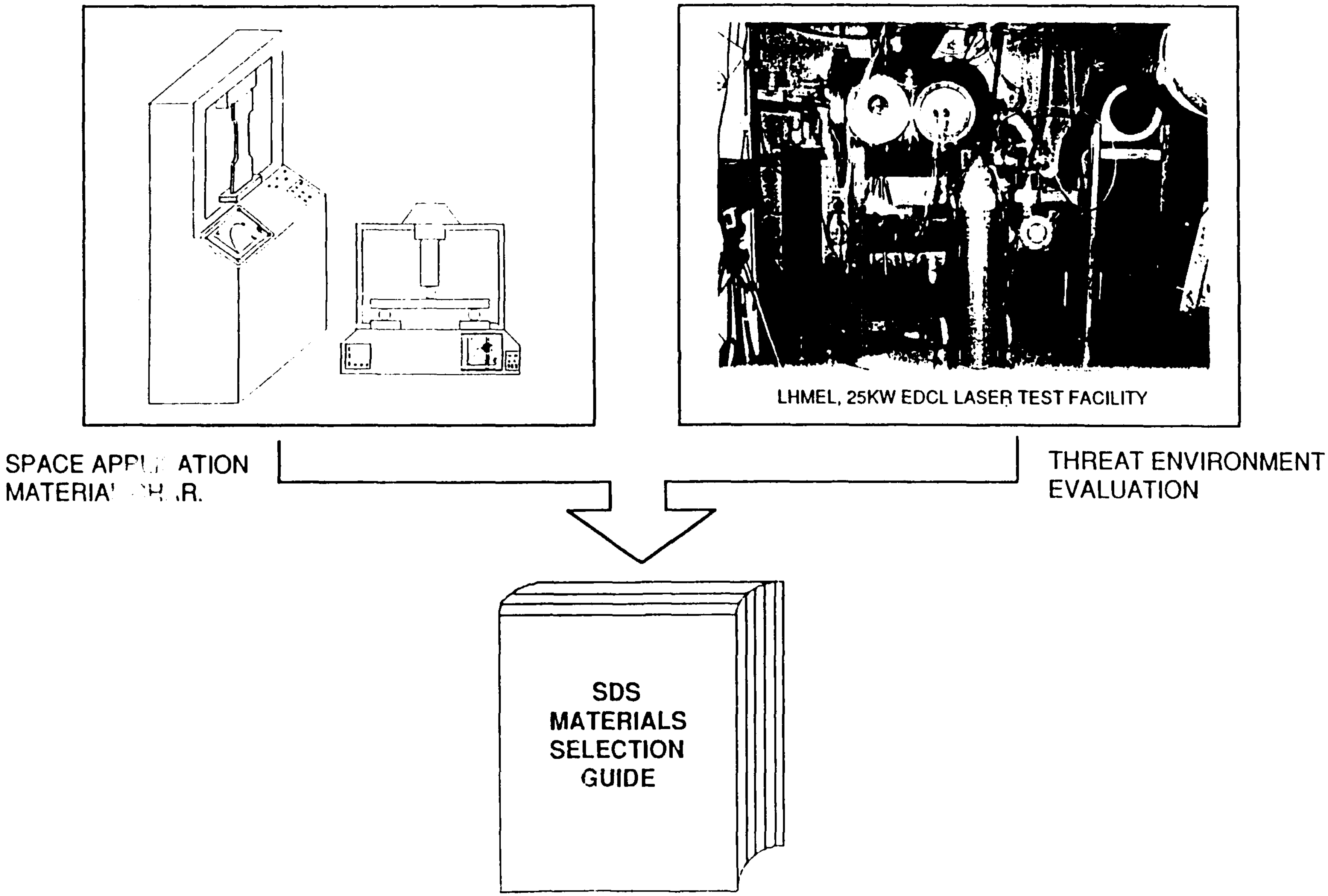
- MATERIAL PROPERTIES
- LEVEL OF TECHNOLOGY MATURITY
- PREVIOUS USAGE AND APPLICATIONS
- MANUFACTURABILITY
- AVAILABILITY
- COST (MATERIAL AND MANUFACTURING)
- VALIDITY OF ABOVE INFORMATION

KETEMA CMD

MATERIAL EVALUATION PROGRAM OBJECTIVES

- EVALUATE PERFORMANCE AND SURVIVABILITY ATTRIBUTES OF ADVANCED MATERIALS FOR SDI APPLICATION
- GENERATE DATA AND INFORMATION THAT S/C DESIGN ENGINEERS CAN USE FOR TRADE STUDIES AND PRELIMINARY DESIGN
- PROVIDE A PROCEDURE FOR ON-GOING EVALUATION OF ADVANCED MATERIALS
- PROVIDE MATERIAL DEVELOPMENT GUIDANCE

MATERIAL EVALUATION PROGRAM



Objective

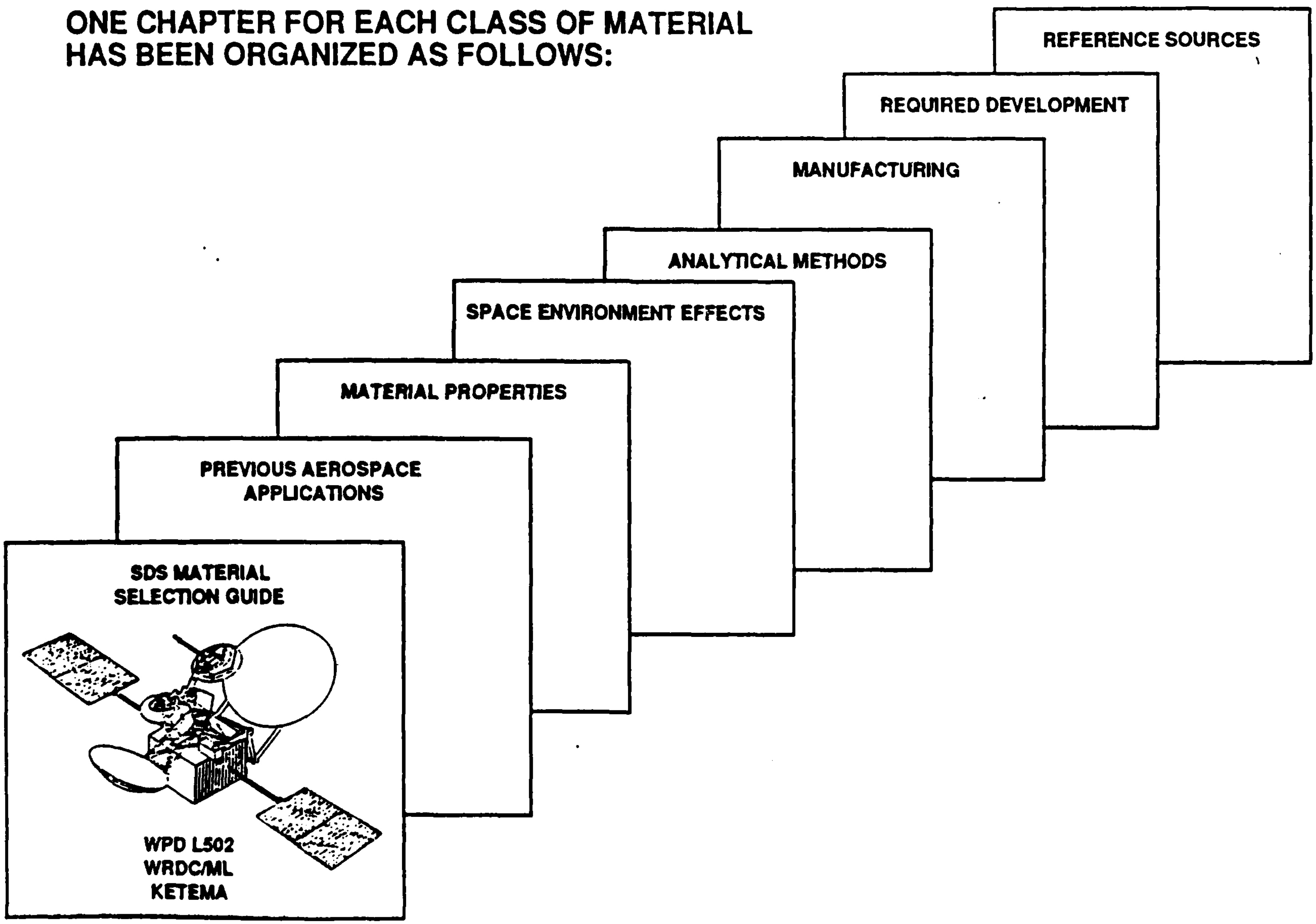
- Generate Mechanical, Thermal, and Physical Property Test Data for Advanced Structural Materials
  - To aid in the selection of materials for spacecraft structural applications, and
  - To guide in related research and development activities
- *First Year Effort*
  - Conduct comparative tests of flat panels and lightly loaded tubes of various composites
  - Perform thermal cycling tests to simulate service in space for periods of up to 10 years

MARTIN MARIETTA

KETEMA CMD

MATERIALS SELECTION GUIDE CONTENTS

ONE CHAPTER FOR EACH CLASS OF MATERIAL HAS BEEN ORGANIZED AS FOLLOWS:



MATERIAL SELECTION GUIDE CONTENTS

SUBSECTION TITLE	DESCRIPTION OF CONTENTS
MATERIAL SYSTEM APPLICATION	- PREVIOUS AEROSPACE APPLICATIONS OF THE SPECIFIC MATERIAL SYSTEM - DESCRIPTION OF MATERIALS SYSTEM DESIGN, FABRICATION, AND TEST EXPERIENCE AND ANY IN-SERVICE HISTORY
PROPERTY DATA DESCRIPTION	- DESCRIPTION OF THE QUANITY AND QUALITY OF THE AVAILABLE DATA FOR SPECIFIC MATERIAL SYSTEM - REFERENCES TO TEST METHODS FOR MATERIAL SYSTEM DATA ACQUISITION - IDENTIFICATION OF ANY EXISTING DATA BASES
MATERIALS PROPERTIES	- PHYSICAL MECHANICAL, THERMAL, ELECTRICAL/OPTICAL PROPERTIES FOR SPECIFIC MATERIAL SYSTEMS - DATA IS FROM NON-PROPRIETARY SOURCES ONLY
ENVIRONMENTAL EFFECTS	- DESCRIPTION OF SPACE ENVIRONMENTAL EFFECTS FOR THE SPECIFIC MATERIALS SYSTEM CATEGORIZED BY: THREAT ENVIRONMENT (LASER, NUCLEAR, KINETIC ENERGY) EFFECTS (AVAILABLE IN A CLASSIFIED APPENDIX) NATURAL ENVIRONMENT EFFECTS (THERMAL CYCLING, VACUUM)
ANALYTICAL TOOLS	- REFERENCES TO ANALYTICAL AND DESIGN METHODS WHICH ARE APPLICABLE TO THE SPECIFIC MATERIAL SYSTEMS
MANUFACTURING	- MANUFACTURING CHARACTERISTICS TO INCLUDE: MANUAL AND AUTOMATED MANUFACTURING PROCESSES MATERIAL PROCESSING/CURE CYCLES TOOLING AND FABRICATION/JOINING METHODS QUALITY CONTROL AND REPAIR PROCEDURES
TECHNOLOGY DEVELOPMENT	- IDENTIFICATION OF THE SPECIFIC MATERIAL SYSTEM STATE-OF-THE-ART (SOA) AS APPLIED TO MATERIAL READINESS FOR SYSTEM APPLICATION - DESCRIPTION OF THE SPECIFIC MATERIAL SYSTEM DEVELOPMENT WORK (WHERE APPLICABLE) REQUIRED TO ADVANCE THE MATERIAL SYSTEM SOA TO MATURITY
REFERENCE DATA	- LISTING OF REFERENCE DATA/MATERIAL WHICH WERE USED TO COMPILE THE SPECIFIC MATERIAL SYSTEM SECTION
OTHER SOURCES	- BIBLIOGRAPHY OF ADDITIONAL SOURCES OF INFORMATION

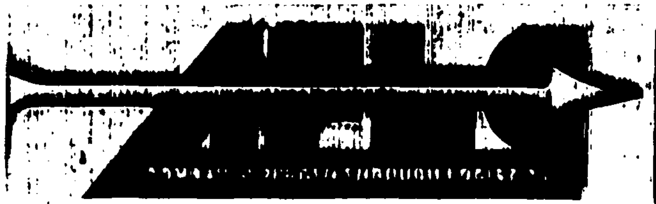
KETEMA CMD

SUMMARY

- MATERIAL EVALUATION IS ESSENTIAL TO ENSURING TECHNOLOGY TRANSITION
- THE MATERIAL EVALUATIONPROGRAM HAS PRODUCED A UNIQUE SET OF DATA/INFORMATION ON ADVANCED MATERIALS
- CONTINUING EFFORT WILL LEAD TO KEY INFORMATION THAT ENHANCES DEVEOPMENT OF ADVANCED MATERIALS FOR SDI APPLICATIONS

ADVANCED METALS AND CERAMICS, TAPM

In the topic, Advanced Metals and Ceramics, Steven Knight (SA-ALC/MMETE, Kelly AFB, Texas) discussed the application of advanced materials to repair problems, and technology transfer approaches for utilizing technology now being developed. Mr. Knight mentioned that Texas University at Austin has made a videotape of a metal matrix composite study course, which is available now to this (MMC) meeting's attendees. It can be requested by contacting him (Knight). Charted information taken from his talk is appended.



INTRODUCTION

- NEW START PROGRAM
  - JUN 86
- ORIGINAL TASKING
  - HTM TAPM
- ADDITIONAL TASKINGS
  - GASEOUS & LIQUID CONNECTORS TAPM, DEC 87
  - IMPROVE HONEYCOMB ENGINEERING DATA, OCT 87
  - SDI SUPPORTABILITY ANALYSIS, AUG 87

INTRODUCTION (CONT'D)

- LIST OF METALS TECHNOLOGY CATEGORIES INCLUDED IN THE HTM PROGRAM:
  - POWDER METALLURGY/RAPID SOLIDIFICATION/ISOSTATIC PRESSING
  - SUPERPLASTIC FORMING/DIFFUSION BONDING
  - METAL MATRIX COMPOSITES
  - LARGE STRUCTURAL CASTINGS
  - METAL-POLYMER COMPOSITE HYBRIDS
  - INTEGRAL DAMPENING
  - SUPER ALLOYS (ADVANCED TURBINE MATERIALS)
  - THERMAL BARRIER COATINGS
  - STRUCTURAL CERAMICS
  - INTERMETALLIC COMPOUNDS
  - ADVANCED INGOT ALLOYS (ALUMINUM/LITHIUM, HIGH TEMPERATURE ALUMINUM, HIGH STRENGTH STEEL, ETC.)
  - ADVANCED METAL FORMING TECHNOLOGY (ELECTROFORMING, STRETCH FORMING, ETC.)
  - ADVANCED METAL FABRICATION TECHNOLOGY (WATERJET CUTTING, LASER DRILLING, ETC.)
  - ADVANCED JOINING PROCESSES (ULTRASONIC WELDING, LASER WELDING, ETC.)
  - ADVANCED METAL COATING PROCESSES (SPRAYED, ION IMPLANTATION, ETC.)
  - SHAPE MEMORY METALS

TECHNOLOGY INSERTION PROJECTS

- E-3A RUDDER PANELS
- F-111 LAUNCHER PIVOT PYLON
- T-38 MULTIPLE PROJECTS
- C-130 LOWER FLAP SKINS
- C-141 UPPER SPOILERS
- HYDRAULIC REPAIR COUPLINGS

TECHNOLOGY TRANSFERS (CONT'D)

- TRAINING (CONT'D)
  - SUPERPLASTIC FORMING & DIFFUSION BONDING
    - - - UT AUSTIN, 8 HRS, 19-28 APR 89
  - POWDER METALLURGY
    - - - UT AUSTIN, 8 HRS, 3-12 MAY 89
  - SUMMER PROFESSOR, JUN - AUG 89
    - - - PROF OF MATS SCI & ENGR, UT AUSTIN
    - - - TWO BASIC METALS COURSES, 20 HRS EA
    - - - TWO ADV METALS COURSES, 20 HRS EA

TECHNOLOGY TRANSFER EFFORTS

- AFLC CAPABILITY SURVEY
  - EVALUATED ALC's ABILITY TO SUPPORT NEW METALS TECHNOLOGY, AUG 88
- TRAINING
  - DAMPING SEMINAR
    - FLIGHT DYNAMICS LAB, 8 hrs, SEP 87
  - METAL MATRIX COMPOSITES COURSE
    - UT AUSTIN, 16 hrs, NOV-DEC 87

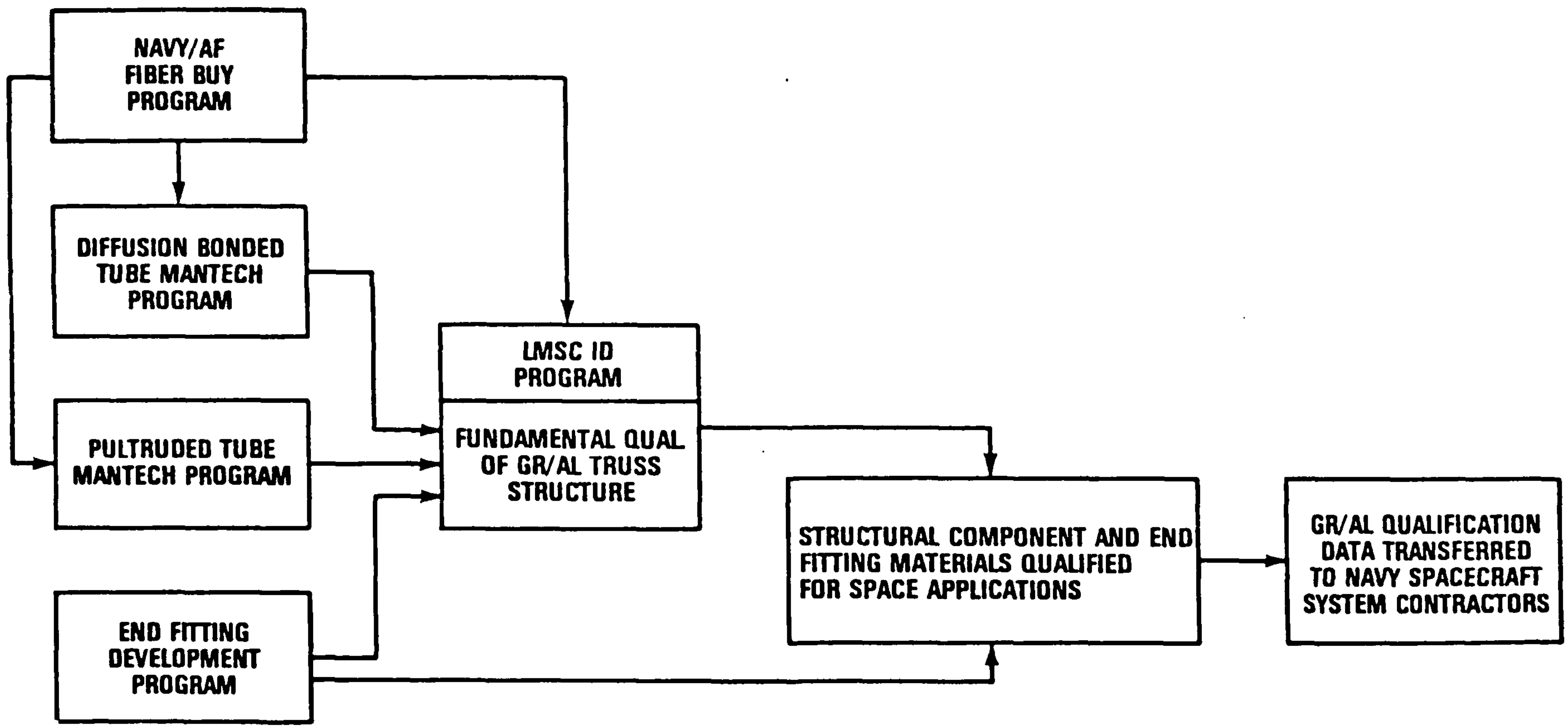
TECHNOLOGY TRANSFER (CONT'D)

- HTM HANDBOOK
  - 16 SECTIONS
    - -- 3 COMPLETE
    - -- 3 IN DRAFT
    - -- 6 ON CONTRACT
    - -- 4 FY90 BUDGET
- OC-ALC TECHNOLOGY APPLICATIONS SEMINAR
  - PARTICIPATED USING DISPLAYS, 18-20 APR 89

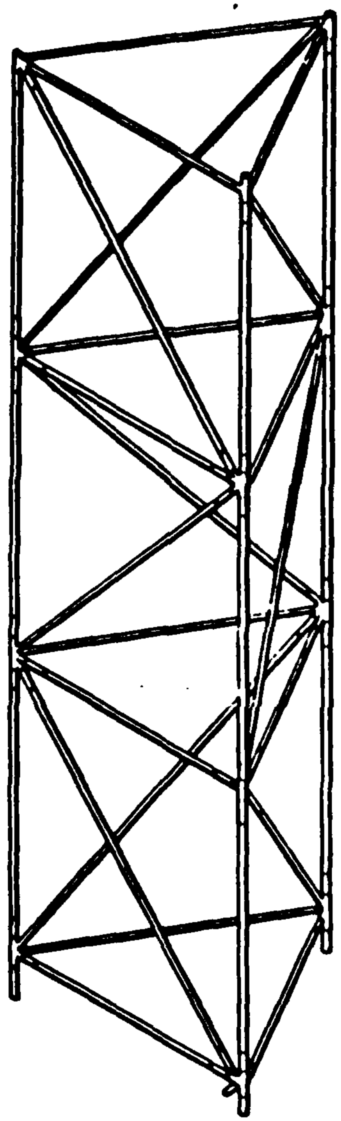
REPRODUCIBLE GR/AL MATERIALS FOR SDI APPLICATIONS

The topic, Reproducible Gr/Al Materials for SDI Applications, presented by Albert L. Bertram (NSWC), related to the Lockheed program on these materials. Copies of several of the viewgraphs used by Mr. Bertram in his presentation are included here.

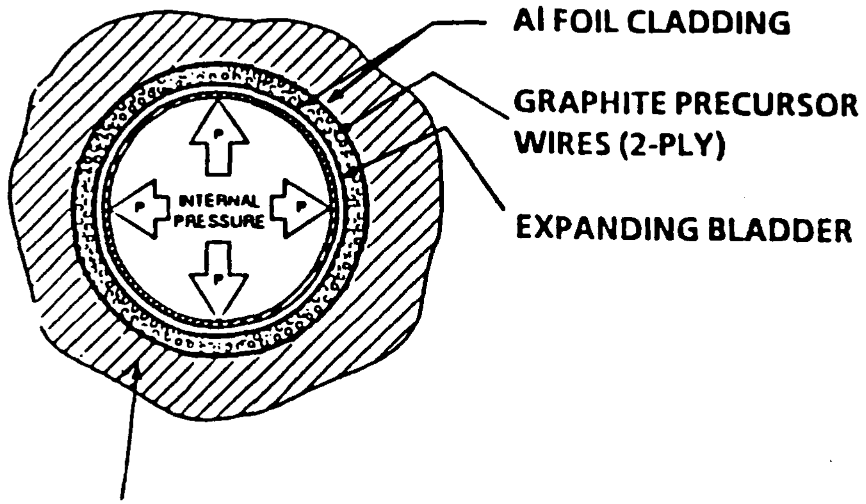
SPACE MATERIAL QUALIFICATION



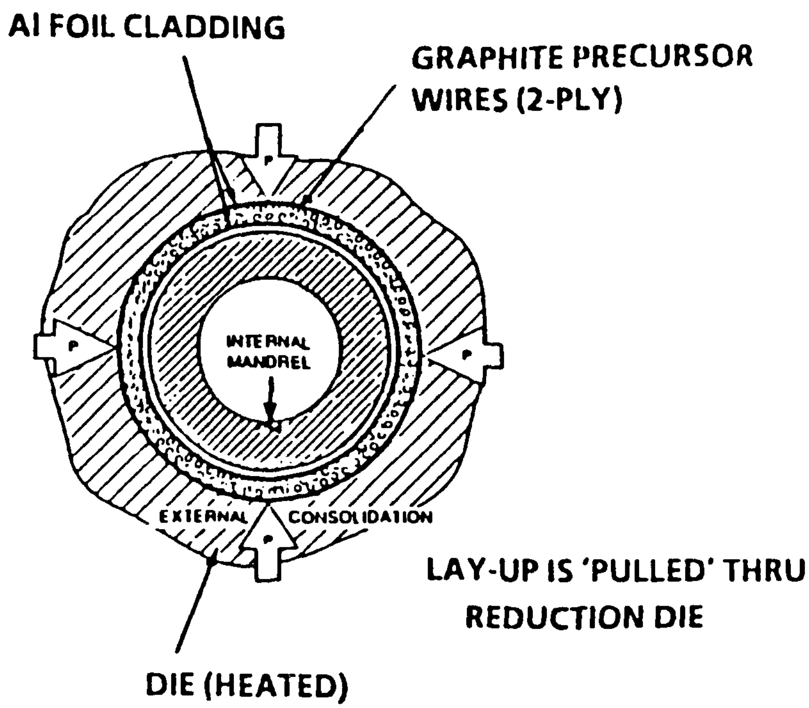
SINGLE 3-BAY TRUSS CONFIGURATION



FABRICATION TECHNIQUES FOR Gr/Al TUBES



DIFFUSION BONDING



PULTRUSION

SPECIFICATION FOR GRAPHITE/ALUMINUM TUBES

	LONGERONS & DIAGONALS		BATTENS	
	DIFFUSION BONDED	PULTRUDED	DIFFUSION BONDED	PULTRUDED
LAYUP (NO. LAYERS UNIDIRECTIONAL)	2	2	1	1
WALL THICKNESS (IN.): ±0.003 (+0.0045 ACCEPTABLE AT FOIL OVERLAP)	0.040	0.044	0.024	0.023
FIBER VOLUME: ± 0.02	0.45	0.45	0.40	0.43
OUTSIDE DIAMETER (IN.): ± 0.010	1.056	1.085	1.017	1.038
LENGTH (IN.): –0/+0.5	70.2	70.2	51.3	51.3
MECHANICAL PROPERTIES				
LONGITUDINAL TENSION MODULUS (Msi)	45 min.	45 min.	43 min.	43 min.
(GPa)	310 min.	310 min.	296 min.	296 min.
LONGITUDINAL TENSION STRENGTH (ksi)	85 min.	85 min.	85 min.	85 min.
(GPa)	0.059 min.	0.059 min.	0.059 min.	0.059 min.
LONGITUDINAL COMPRESSION MODULUS (Msi)	45 min.	45 min.	43 min.	43 min.
(GPa)	310 min.	310 min.	296 min.	296 min.
LONGITUDINAL COMPRESSION STRENGTH (ksi)	30 min.	30 min.	25 min.	25 min.
(GPa)	0.021 min.	0.021 min.	0.017 min.	0.017 min.

ALL TUBES

VOIDS $\leq$ 1.5%

OVALITY (MAX–MIN) = 0.010 IN. MAXIMUM

BOW $\leq$ 0.008 IN. PER FOOT (ALONG ANY AXIAL LINE CONTACT)

TWIST $\leq$ 0.010 DEGREE PER FOOT

FOIL CLAD BOND QUALITY — ANY LOCAL DELAMINATION GREATER THAN 0.20 INCH DIAMETER IS CAUSE FOR REJECTION. ANY BLISTERS, PIN HOLES OR THROUGH CLAD SCRATCHES ARE CAUSE FOR REJECTION.

090504/ORIG/BERTRAM/WO

TEST RESULTS – 2-PLY PRODUCTION TUBES

GEOMETRICAL PROPERTIES	DIFFUSION BONDED	PULTRUDED
BOW (IN/FT)		
SPECIFICATION	0.008 MAX.	0.008 MAX.
TEST DATA		
AVERAGE	0.005	0.005
RANGE	0.002 - 0.011	0.002 - 0.010
NO. SPECIMENS (S.D.)	15 (0.002)	17 (0.002)
WALL THICKNESS (IN.)		
SPECIFICATION: +.003/-.003	0.040	0.040
TEST DATA		
AVERAGE	0.039	0.041
RANGE	0.036 - 0.044	0.040 - 0.055
NO. SPECIMENS (S.D.)	15 (0.001)	17 (0.001)
OUTSIDE DIAMETER (IN.)		
SPECIFICATION: +.010/-.010	1.056	1.080
TEST DATA		
AVERAGE	1.055	1.075
RANGE	1.053 - 1.057	1.069 - 1.090
NO. SPECIMENS (S.D.)	15 (0.001)	17 (0.003)
OTHER PROPERTIES		
FIBER VOLUME		
SPECIFICATION: +.02/-.02	0.45	0.45
TEST DATA		
AVERAGE	0.426	0.465
RANGE	0.405 - 0.444	0.455 - 0.476
NO. SPECIMENS (S.D.)	22 (0.012)	17 (0.006)

061516/orig/Bertram

TEST RESULTS – 2-PLY PRODUCTION TUBES

MECHANICAL PROPERTIES	DIFFUSION BONDED	PULTRUDED
LONGITUDINAL TENSION		
TENSILE MODULUS (Msi)		
SPECIFICTION	45 MIN.	45 MIN.
TEST DATA		
AVERAGE	56.5	56.7
RANGE	53.4 - 59.3	55.7 - 57.3
NO. SPECIMENS (S.D.)	5 (2.2)	4 (0.7)
TENSILE STRENGTH (ksi)		
SPECIFICATION	85 MIN.	85 MIN.
TEST DATA		
AVERAGE	110.0	TBD
RANGE	87.7 - 132.3	
NO. SPECIMENS (S.D.)	2 (31.5)	
LONGITUDINAL COMPRESSION		
COMPRESSIVE MODULUS (Msi)		
SPECIFICATION	45 MIN.	45 MIN.
TEST DATA		
AVERAGE	53.1	55.6
RANGE	49.9 - 56.0	53.7 - 58.0
NO. SPECIMENS (S.D.)	4 (2.6)	4 (1.9)
COMPRESSIVE STRENGTH (ksi)		
SPECIFICATION	30 MIN.	30 MIN.
TEST DATA		
AVERAGE	39.9	41.9
RANGE	37.2 - 42.0	39.9 - 43.6
NO. SPECIMENS (S.D.)	4 (2.3)	4 (1.5)

061516/orig/Bertram

TEST RESULTS – 1-PLY PRODUCTION TUBES

GEOMETRICAL PROPERTIES	DIFFUSION BONDED	PULTRUDED
BOW (IN/FT)		
SPECIFICATION	0.008 MAX.	0.008 MAX.
TEST DATA		
AVERAGE	0.004	0.004
RANGE	0.001 - 0.008	0.002 - 0.007
NO. SPECIMENS (S.D.)	12 (0.002)	14 (0.001)
WALL THICKNESS (IN.)		
SPECIFICATION: +.003/-.003	0.024	0.023
TEST DATA		
AVERAGE	0.022	0.023
RANGE	0.020 - 0.026	0.022 - 0.025
NO. SPECIMENS (S.D.)	12 (0.001)	14 (0.000)
OUTSIDE DIAMETER (IN.)		
SPECIFICATION: +.010/-.010	1.017	1.038
TEST DATA		
AVERAGE	1.015	1.037
RANGE	1.011 - 1.021	1.035 - 1.040
NO. SPECIMENS (S.D.)	12 (0.002)	14 (0.001)
OTHER PROPERTIES		
FIBER VOLUME		
SPECIFICATION: +.02/-.02	0.40	0.43
TEST DATA		
AVERAGE	0.380	0.419
RANGE	0.364 - 0.403	0.413 - 0.427
NO. SPECIMENS (S.D.)	14 (0.011)	14 (0.004)

061516/orig/Bertram

TEST RESULTS – 1-PLY PRODUCTION TUBES

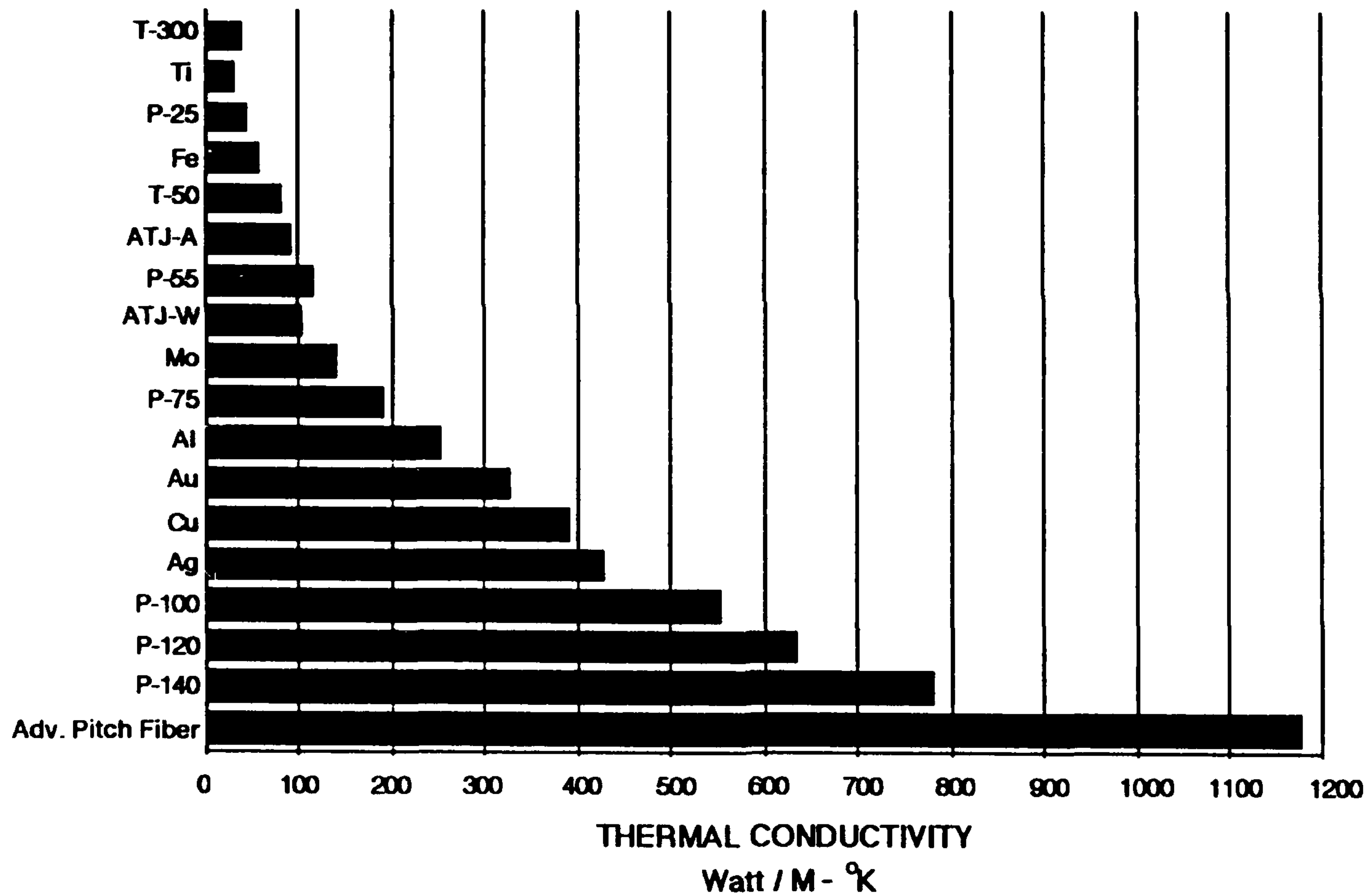
MECHANICAL PROPERTIES	DIFFUSION BONDED	PULTRUDED
LONGITUDINAL TENSION		
TENSILE MODULUS (Msi)		
SPECIFICTION	43 MIN.	43 MIN.
TEST DATA		
AVERAGE	52.2	53.0
RANGE	48.6 - 56.4	51.4 - 55.2
NO. SPECIMENS (S.D.)	4 (3.8)	4 (1.6)
TENSILE STRENGTH (ksi)		
SPECIFICATION	85 MIN.	85 MIN.
TEST DATA		
AVERAGE	85.4	101.6
RANGE	85.4	101.6
NO. SPECIMENS (S.D.)	1 (–)	1 (–)
LONGITUDINAL COMPRESSION		
COMPRESSIVE MODULUS (Msi)		
SPECIFICATION	43 MIN.	43 MIN.
TEST DATA		
AVERAGE	51.6	52.4
RANGE	48.2 - 54.9	50.3 - 53.4
NO. SPECIMENS (S.D.)	4 (3.7)	4 (1.4)
COMPRESSIVE STRENGTH (ksi)		
SPECIFICATION	25 MIN.	25 MIN.
TEST DATA		
AVERAGE	35.7	39.0
RANGE	32.1 - 39.7	36.9 - 40.8
NO. SPECIMENS (S.D.)	4 (3.1)	4 (1.7)

061516/orig/Bertram

TRUSS STATUS

- REPRODUCIBLE Gr/Al TUBES DEVELOPED
- END FITTING MANUFACTURING METHOD ESTABLISHED
- FIRST Gr/Al TRUSS ASSEMBLED AND SUCCESSFULLY TESTED
  - STATIC LOADING
  - RESONANCE MODAL SURVEY
- SECOND Gr/Al TRUSS ASSEMBLED
  - TESTING EXPECTED TO START IN NOVEMBER
- QUALIFICATION SiC/Al TUBES RECEIVED

THERMAL CONDUCTIVITY OF METALS AND CARBONS



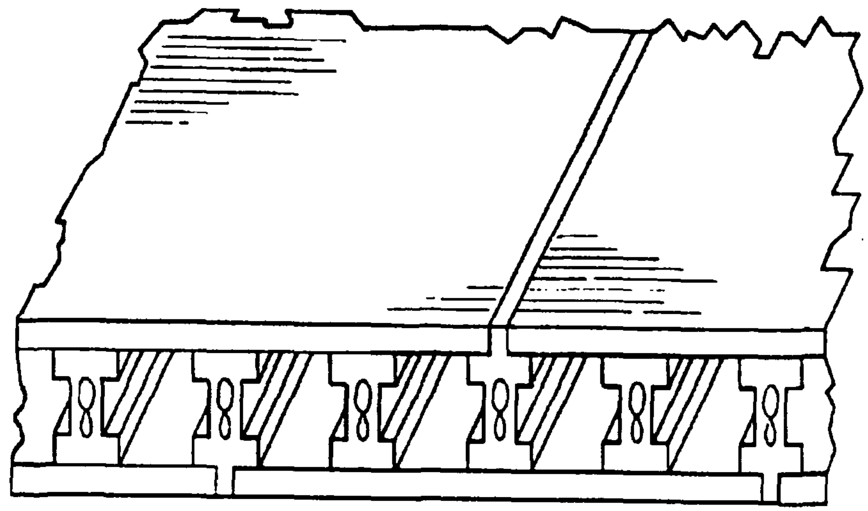
WJSA-D9-DV-3

GRAPHITE / ALUMINUM RADIATOR

BACKGROUND

5 - 10 KW THERMAL MANAGEMENT REQUIRED FOR SURVIVABLE SYSTEMS

RADIATORS REPRESENT 20 - 40% OF SPACECRAFT STRUCTURAL MASS



OBJECTIVES

TO DEVELOP AN ADVANCED SURVIVABLE RADIATOR USING THIN PLY PANELS EXHIBITING HIGH THERMAL CONDUCTIVITY, LOW COEFFICIENT OF THERMAL EXPANSION, AND HIGH ATOMIC OXYGEN RESISTANCE FOR USE IN THE 50K - 1000K TEMPERATURE REGIME

APPROACH

- DEVELOP THIN PLY Gr / Al TO PRE - PRODUCTION STATE
- DEVELOP LASER TEST ARTICLES
- MMC SHEET & TUBE MANUFACTURABILITY SCALE - UP
- FABRICATE CRITICAL SPACE STRUCTURE ELEMENTS
- ACCRUE WEIGHT & COST DATA FOR DEMONSTRATOR MATERIAL SELECTION
- APPLY MATERIALS TO DESIGN OF A THERMAL RADIATOR

PAYOFF

10 - 50% WEIGHT SAVINGS DEPENDING ON THE RADIATOR

RELEVANT APPLICATIONS

PRIMARY: BSTS, SSTS

SECONDARY: SBI AND OTHER DEW SYSTEMS

WJSA-D9-CM-2

SPACECRAFT RADIATOR PANEL DEVELOPMENT

OBJECTIVE: DEVELOP THIN PLY GR/AL PANELS FOR SPACECRAFT RADIATOR APPLICATIONS

STATUS:

- PRELIMINARY CONFIGURATIONS DELIVERED

LAYUP	NUMBER LAYERS	THICKNESS (MILS)
O_2	3	14.5
$(+11/-11)_S$	4	12.0
$(O_2 /90/O_2)$	5	12.5

- SCALE UP UNDERWAY
  - 2 FT X 5 FT 11-12 MIL PANELS FABRICATED
    GOOD SURFACE QUALITY

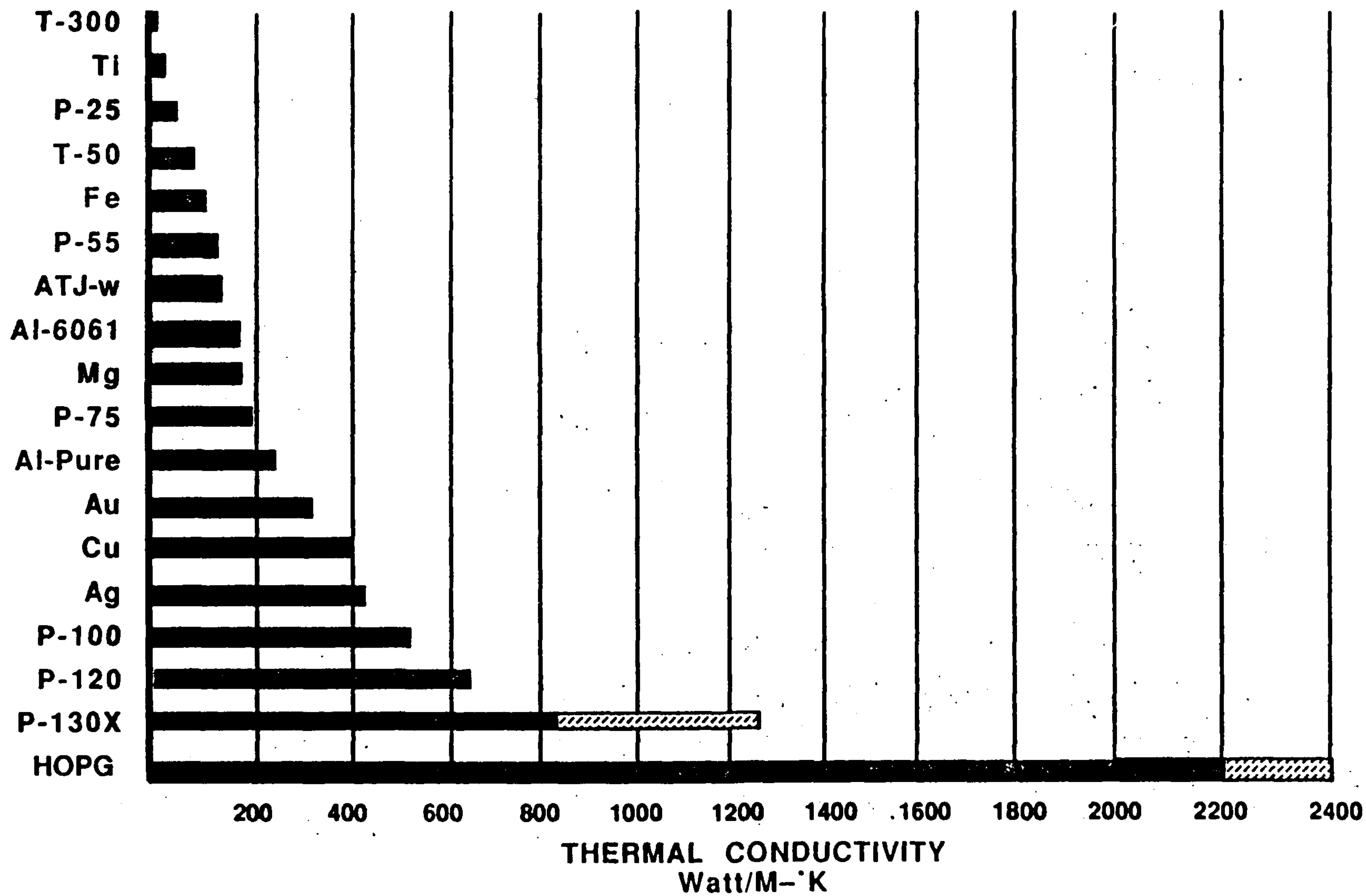
090504/ORIG/BERTRAM/WO

SUMMARY OF P120 Gr/6061 AL TEST RESULTS

Property	Unit	Gr/AL P120/6061 AL [0] Theoretical	Gr/AL #1770 $[0]_3$ Measured	Gr/AL #1807 $[\pm 11]_s$ Measured
Fiber Volume Fraction	%	45	41.2	46.2
Density	g/cm^3	2.38	2.44	2.45
Young's Modulus – Longitudinal	Msi (GPa)	60 (413.7)	54.1 (378.0)	50.7 (349.6)
Young's Modulus – Transverse	Msi (GPa)	5 (34.5)	5.6 (38.6)	4.0 (27.6)
In-Plane Shear Modulus	Msi (GPa)	3.5 (24.1)		
Poisson's Ratio (Longitudinal-Transverse)		0.3		
Tensile Strength – Longitudinal	ksi (GPa)	100 (0.689)	87.1 (0.601)	89.9 (0.620)
Tensile Strength – Transverse	ksi (GPa)	3 (0.021)	5.9 (0.041)	4.0 (0.028)
Compressive Strength – Longitudinal	ksi (GPa)	30 (0.207)	34.5 (0.238)	31.6 (0.218)
Compressive Strength – Transverse	ksi (GPa)	8 (0.552)		
CTE – Longitudinal	ppm/K	0.9		0.41
CTE – Transverse	ppm/K	21.6		
Thermal Conductivity – Longitudinal	W/m • K	375	328	350
Thermal Conductivity – Transverse	W/m • K	86.5		
Specific Thermal Conductivity-Longitudinal	W • cm^3/m•K•g	157.6	134.4	142.9
Maximum Use Temperature	°c (°F)	371 (700)	371 (700)	371 (700)
Melting (Solidus) Temperature	°c (°F)	582 (1080)	582 (1080)	582 (1080)
Outgassing		No	No	No

090504/ORIG/BERTRAM/WO

THERMAL CONDUCTIVITY OF SELECTED MATERIALS: COMPARISON OF METALS, CARBONS, AMD CARBON FIBERS

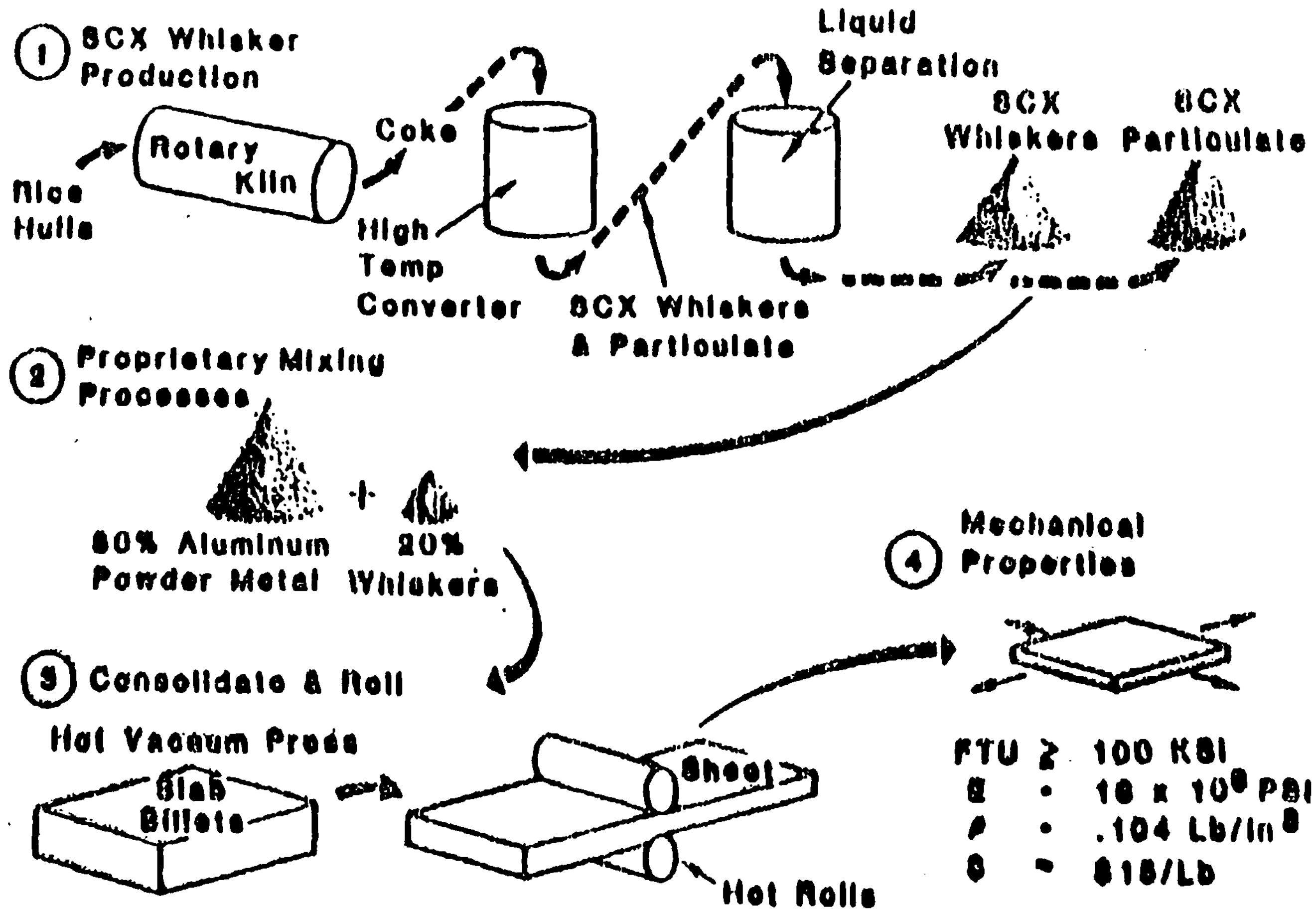


0510'bertram

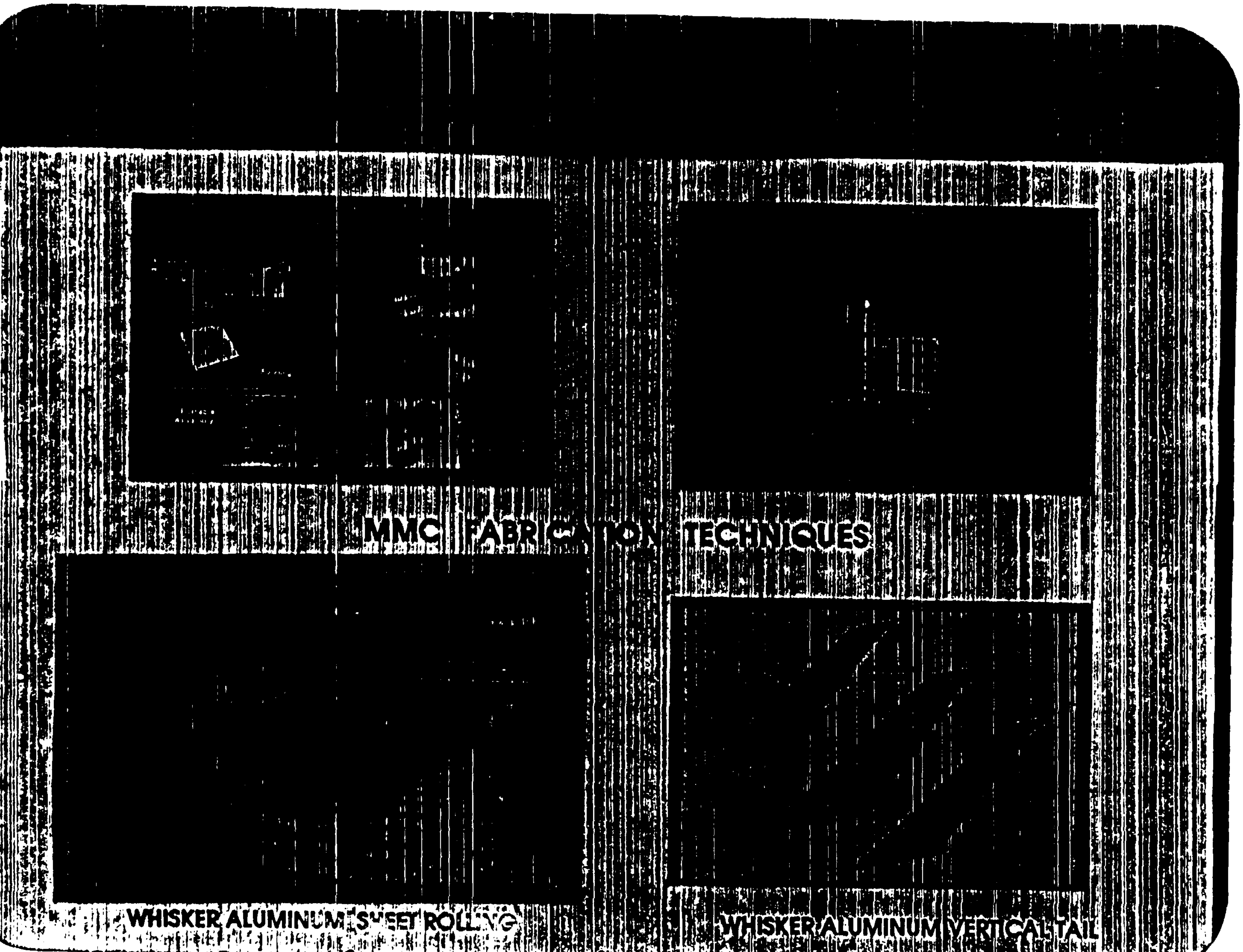
ADVANCED METALLIC STRUCTURES

Copies of viewgraphs used by Verner Johnson (WRDC) in his talk on Advanced Metallic Structures such as metal matrix composites for aircraft tail assemblies are reproduced. It was mentioned that in the work being carried out there was a need for MIL HANDBOOK 5 data which has not been available.

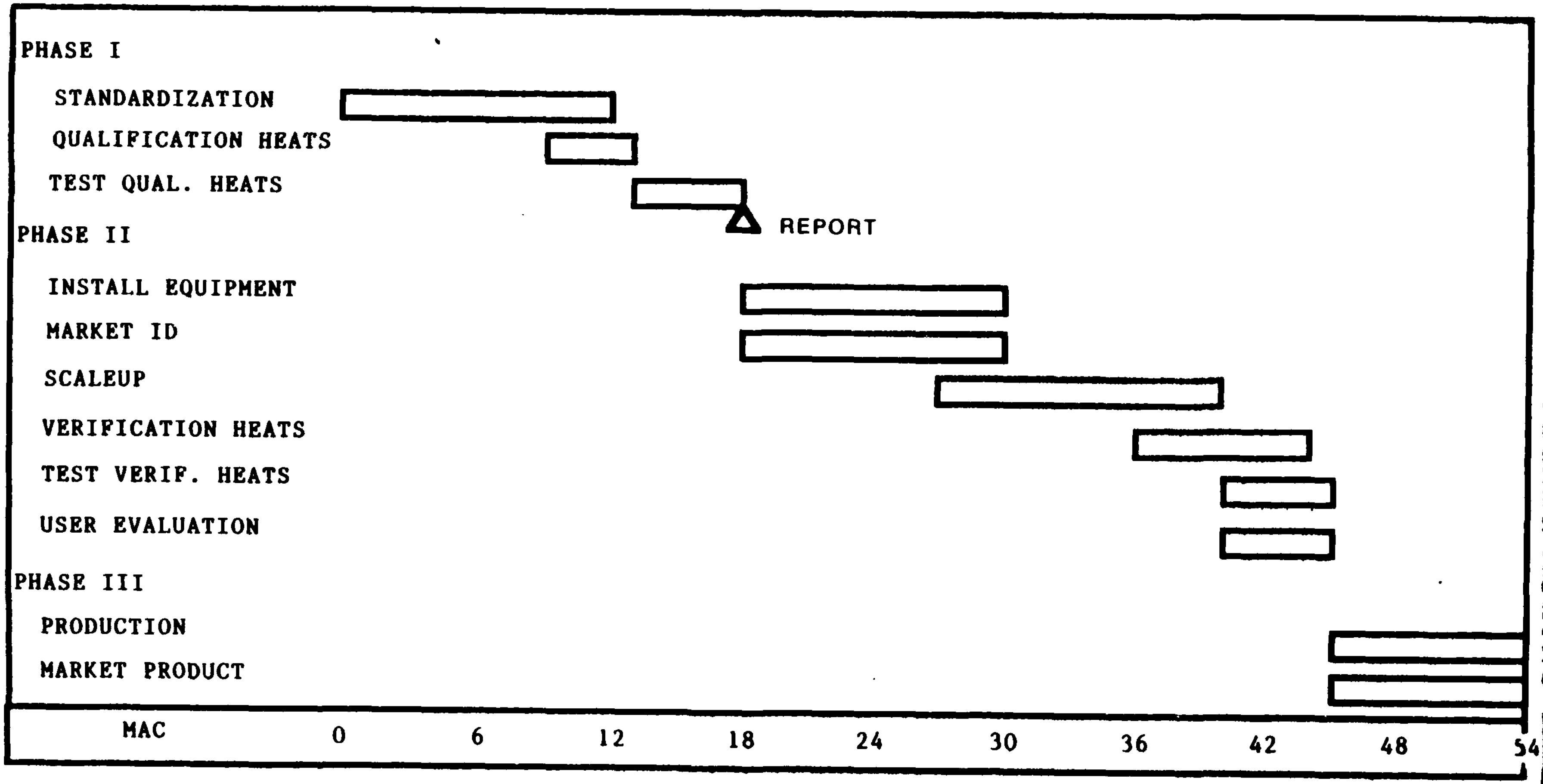
Whisker/Aluminum Production




SiC$_W$ / Al
SiC$_F$ / Al


MMC FABRICATION TECHNIQUES
WHISKER ALUMINUM SHEET ROLLING
WHISKER ALUMINUM VERTICAL TAIL

PROGRAM SCHEDULE

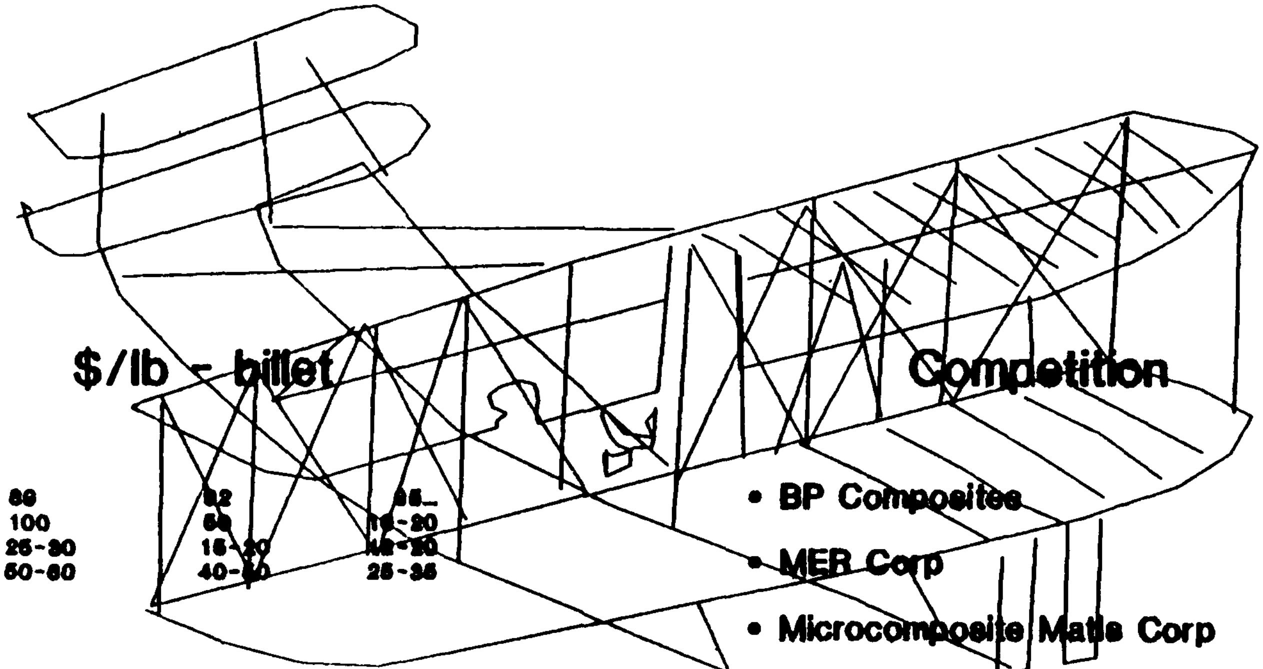


lb/year capacity

company	89	92	95...
ACMC	60,000	170,000	Expandable
DWA	35,000	50-100,000	250,000

Billet Size Capacity

COMPANY	89	92	95...
ACMC	250	575	
DWA	400	500	500



$/lb - billet

COMPANY	89	92	95...
ACMC	100	[illegible]	[illegible]-20
DWA	25-30	15-[illegible]	[illegible]-20
	50-60	40-[illegible]	25-35

Competition

- BP Composites
- MER Corp
- Microcomposite Matls Corp
- other small and foreign companies

SPECIFICATION DEVELOPMENT FOR METAL MATRIX COMPOSITES

Mr. Frank T. Traceski (Defense Quality and Standardization Office) discussed the specification developments for metal matrix composites. A summary position paper on this topic, which was distributed to the meeting attendees, is attached.

Department of Defense

Metal Matrix Composites Steering Committee

Meeting of October 6, 1989

Mr. Frank T. Traceski
Defense Quality and Standardization Office
5203 Leesburg Pike (Suite 1403)
Falls Church, Virginia 22041-3466

(703) 756-2343 or AV 289-2343

Specification Developments for Metal Matrix Composites

The Defense Quality and Standardization Office (DQSO) oversees the implementation of the Department of Defense Standardization Program Plan for Composites Technology. This program plan encompasses the development of specifications for metal matrix composites. The U.S. Army Materials Technology Laboratory is the Lead Standardization Activity for this area.

The two primary military specifications currently under development for metal matrix composites are as follows:

1. MIL-M-XXXXX, Carbon (graphite) reinforced aluminum (Gr/Al) metal matrix composites

2. MIL-M-XXXXX, Silicon carbide reinforced magnesium (Si/Mg) metal matrix composites

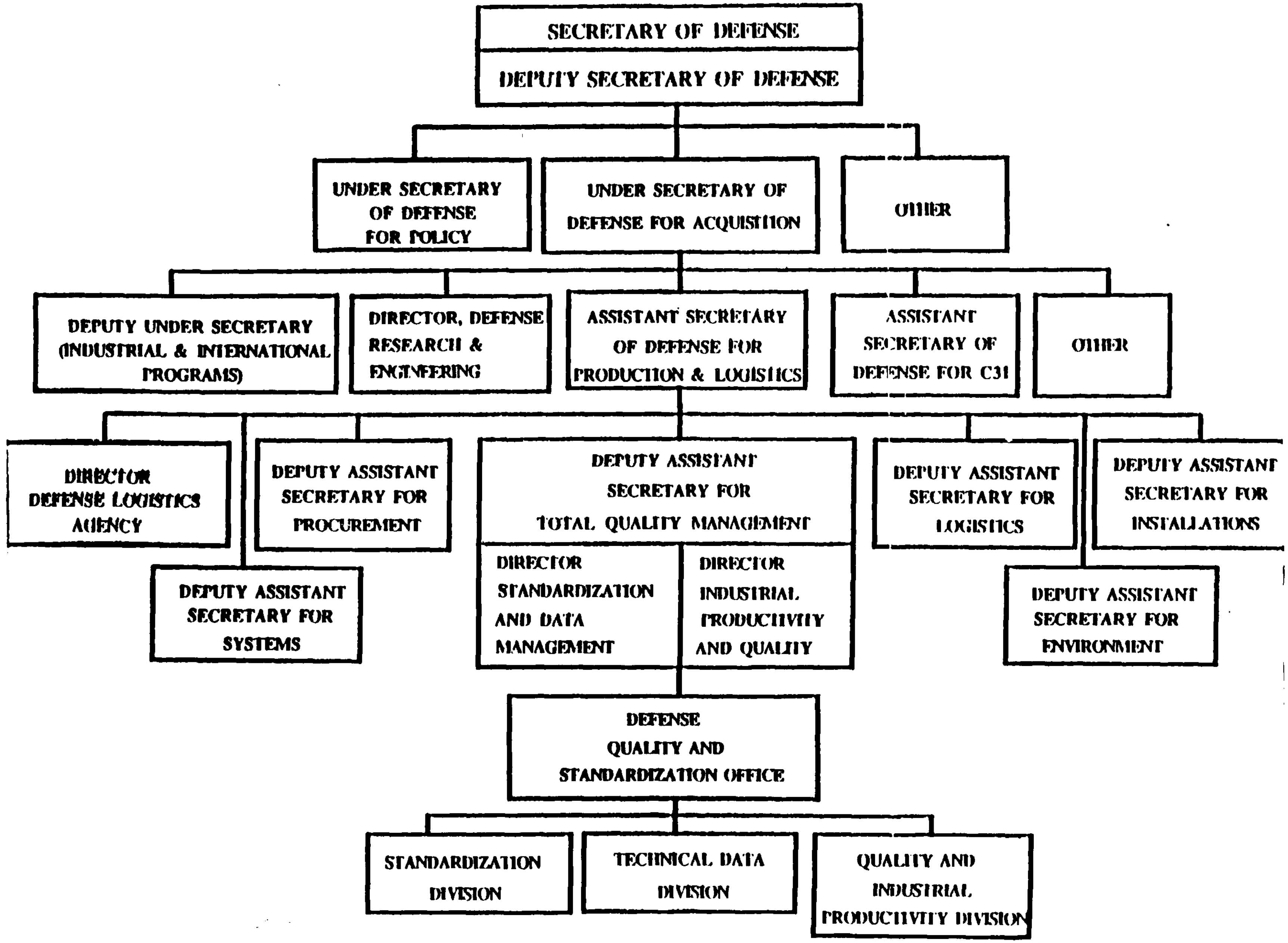
Both of these specifications are being prepared by the U.S. Army Materials Technology Laboratory.

The development of the Gr/Al MMC specification was initiated at the MMC workshop in March 1989. Several drafts have been prepared and coordinated with the services and the aerospace industry. Substantial feedback has been obtained from the Navy and Air Force, material suppliers, and others. The Gr/Al MMC specification is divided into four principal parts. The draft specification includes a general part which covers requirements for testing and quality assurance. Three other parts, designated as detail specifications, specify requirements for carbon fiber reinforced aluminum metal matrix composites for : (1) electronic modules for heat sinks, (2) space radiators, and (3) tubing for space trusses. The next draft will be sent out for coordination in October. The planned completion date for publication is May 15, 1990. Point of contact is Mr. Michael Castro (Army-MTL) at (617) 923-5567.

A specification for silicon carbide reinforced magnesium metal matrix composites is also being prepared by the U.S. Army Materials Technology Laboratory. Ongoing work includes mechanical property testing and physical examination of microstructures. A first draft is being prepared. Mr. Perry Smoot at the Army-MTL is the point of contact, (617) 923-5289. The SiC/Mg material covered by this specification is intended for ballistic applications or structural applications where specific modulus is critical. Specification requirements for tolerances on reinforcement, heat treatment, porosity, and ultrasonic nondestructive testing will be studied as part of this project. Target completion date is October 1990.

The Department of Defense standardization program plan for composites also calls for development of a new military handbook for metal matrix composites. The purpose of this longer-term project is to provide standardized material property data for engineering design of MMC applications. At this time a strategy needs to be developed between various DoD components, in particular the Army and Air Force, to prepare and coordinate an outline of contents for the new handbook. Overlap with ongoing MIL-HDBK-5 needs to be resolved.

There are many other metal matrix composite materials for which specifications need to be developed. The DoD strategy is to prepare individual material and processing specifications for each specific material fiber reinforcement/metal matrix combination (e.g., Gr/Al, SiC/Al, etc.). Variations in fiber content, alloy compositions, or other variables can be handled in separate detail specifications. Development of these specifications is necessary to promote the development and use of these materials in DoD aerospace applications where the attributes of MMCs can be exploited.


SECRETARY OF DEFENSE
DEPUTY SECRETARY OF DEFENSE
UNDER SECRETARY OF DEFENSE FOR POLICY
UNDER SECRETARY OF DEFENSE FOR ACQUISITION
OTHER
DEPUTY UNDER SECRETARY (INDUSTRIAL & INTERNATIONAL PROGRAMS)
DIRECTOR, DEFENSE RESEARCH & ENGINEERING
ASSISTANT SECRETARY OF DEFENSE FOR PRODUCTION & LOGISTICS
ASSISTANT SECRETARY OF DEFENSE FOR C3I
OTHER
DIRECTOR DEFENSE LOGISTICS AGENCY
DEPUTY ASSISTANT SECRETARY FOR PROCUREMENT
DEPUTY ASSISTANT SECRETARY FOR SYSTEMS
DEPUTY ASSISTANT SECRETARY FOR TOTAL QUALITY MANAGEMENT
DIRECTOR STANDARDIZATION AND DATA MANAGEMENT
DIRECTOR INDUSTRIAL PRODUCTIVITY AND QUALITY
DEPUTY ASSISTANT SECRETARY FOR LOGISTICS
DEPUTY ASSISTANT SECRETARY FOR INSTALLATIONS
DEPUTY ASSISTANT SECRETARY FOR ENVIRONMENT
DEFENSE QUALITY AND STANDARDIZATION OFFICE
STANDARDIZATION DIVISION
TECHNICAL DATA DIVISION
QUALITY AND INDUSTRIAL PRODUCTIVITY DIVISION

FOREIGN BUYOUTS

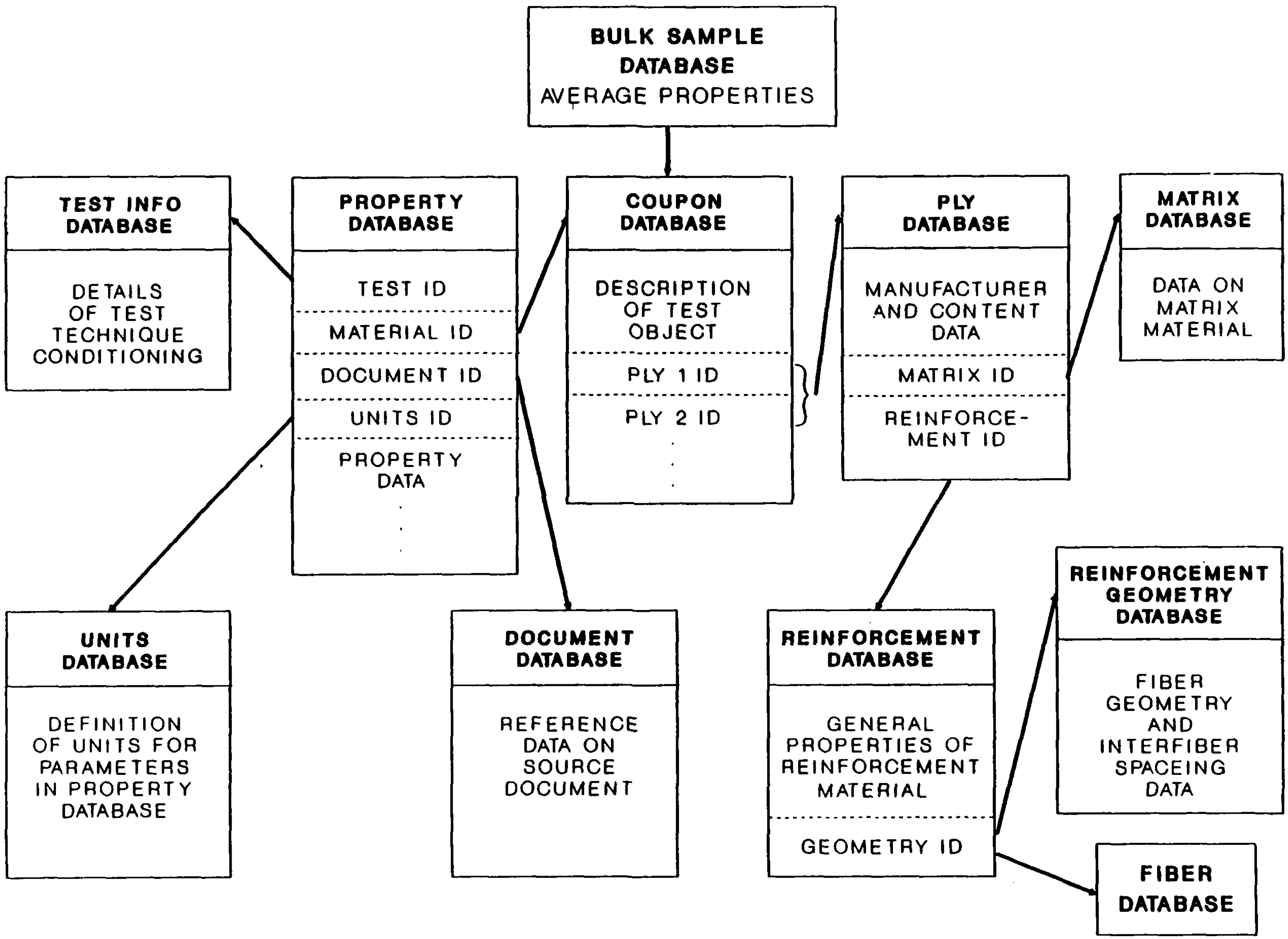
Donald Crafts of the U.S. Department of the Treasury (Office of International Investment) spoke on the subject of Foreign Buyouts of U.S. companies. In this he allowed that U.S. policy has always welcomed foreign investment in this country since its founding in 1776. Such foreign investment is only precluded if it is deemed to be inamicable to U.S. national security. It is restricted also when it related to nuclear energy, and graded in restriction to 25 percent investment in domestic airlines, 25 percent in domestic shipping, and 20 percent of telecommunication industries.

In summary, Mr. Crafts stated that:

- The U.S. essentially maintains an open investment policy.
- The U.S. consumes more than it produces. Hence, we must import capital.
- The U.S. is being challenged economically by Japan now and will be challenged by Europe in the future when the 12 European nations eliminate their national boundaries for economic reasons.

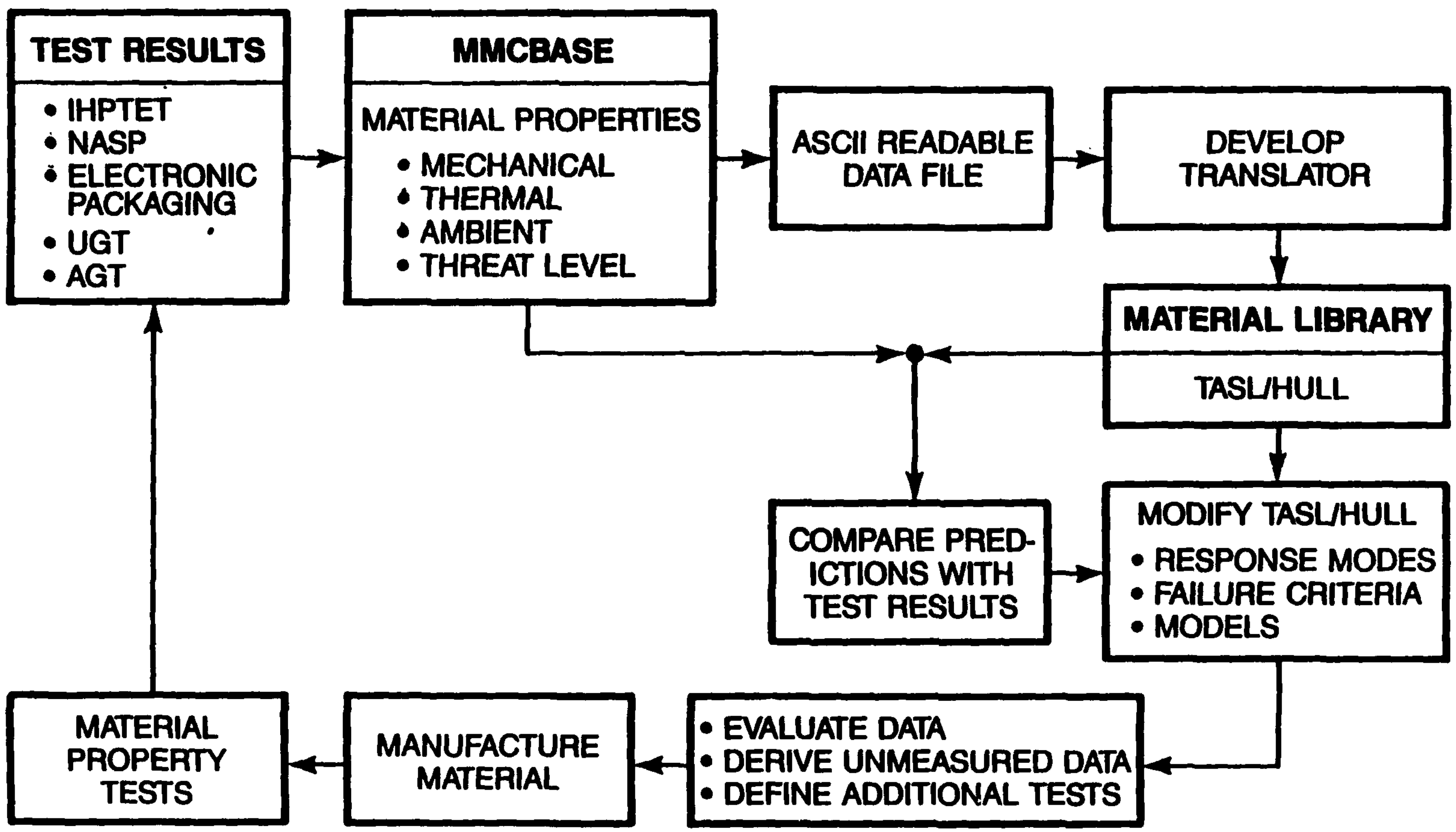
THE MMC NUMERICAL DATABASE

Mr. William McNamara (Kaman-Tempo, Santa Barbara, CA) gave an overview talk on the work of the MMC Numerical Data Base now in progress at the MMC/AC activity in Santa Barbara, CA, where they are using DataBase 4. He recommended that program managers should keep in contact with him regarding a MMC data base format that can be incorporated into their CDRLs. The work has been sponsored by Marlin Kinna (ONT).



MMCBase structure.

RECOMMENDATION: GENERATE DATA AND VALIDATE DATABASE



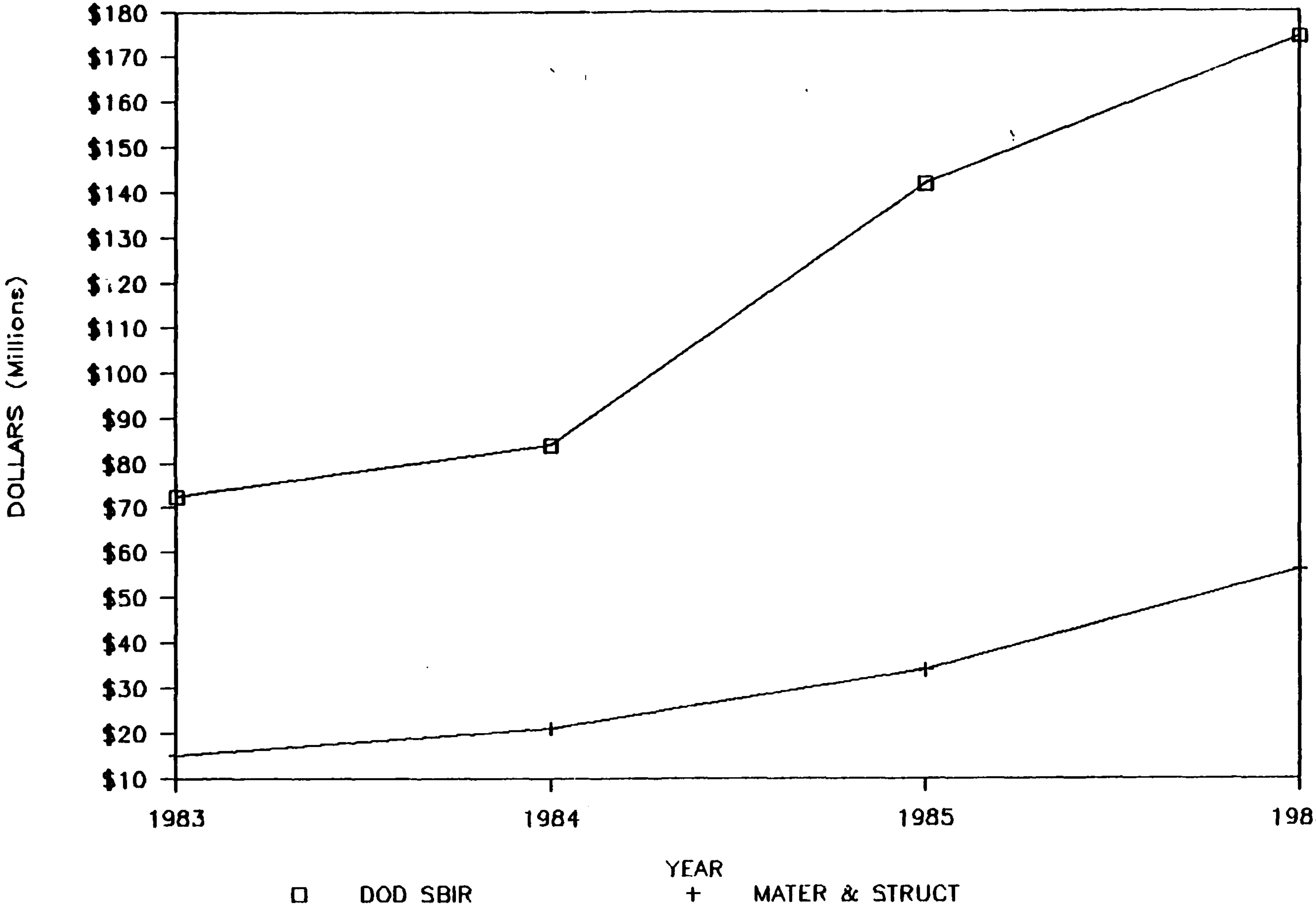
KAMAN

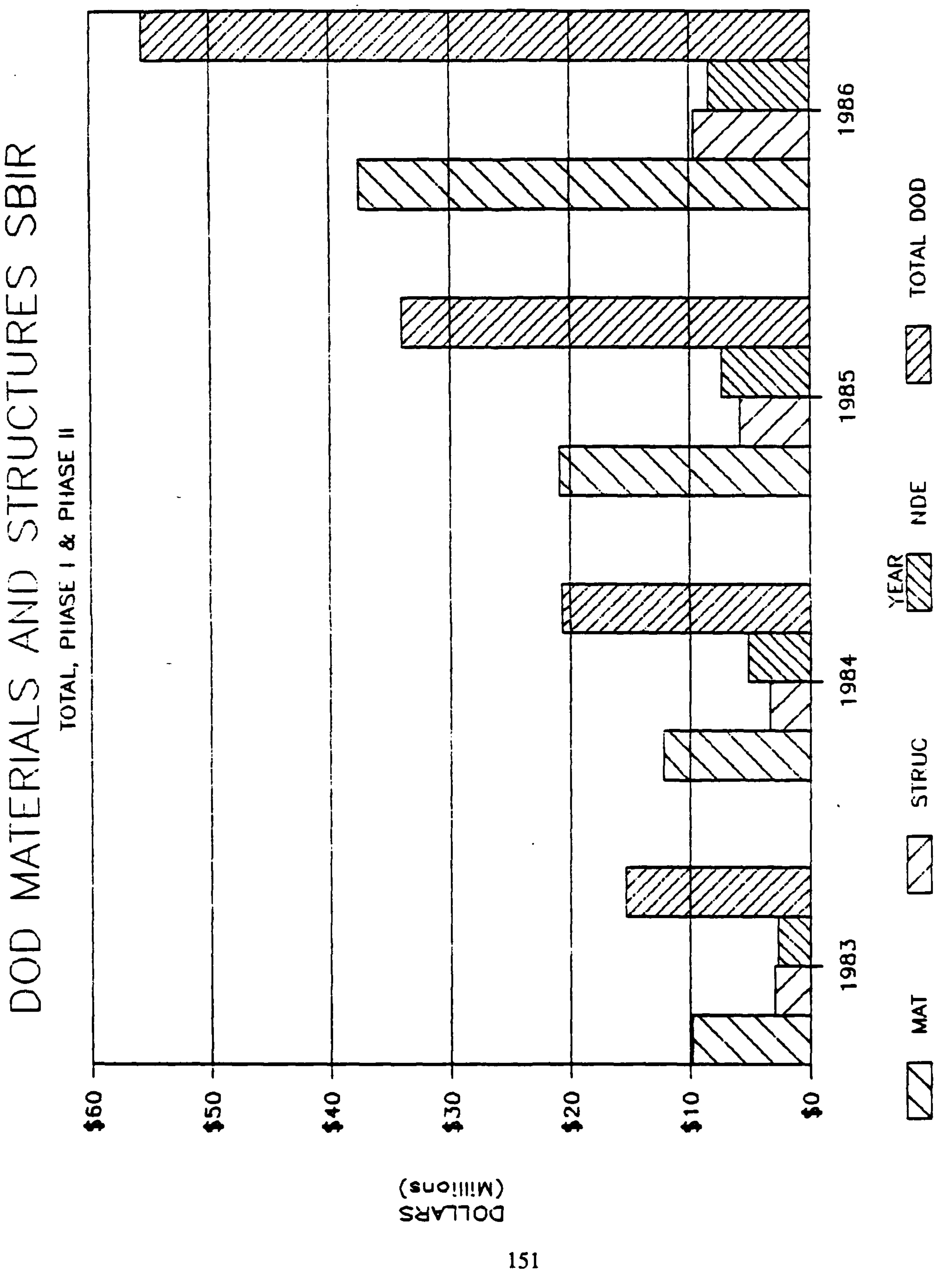
DOD MATERIALS AND STRUCTURES SBIR

Mr. Tom Pojeta of the Defense Technology Assistance Office (OSD-R&AT DLA-DTAO) discussed his work in analyzing the SBIR data compiled for the years 1983-1986 relative to the overall SBIR materials and structures programs including MMCs. The participating contractors were cited. Pertinent charts reflecting this information are attached herein.

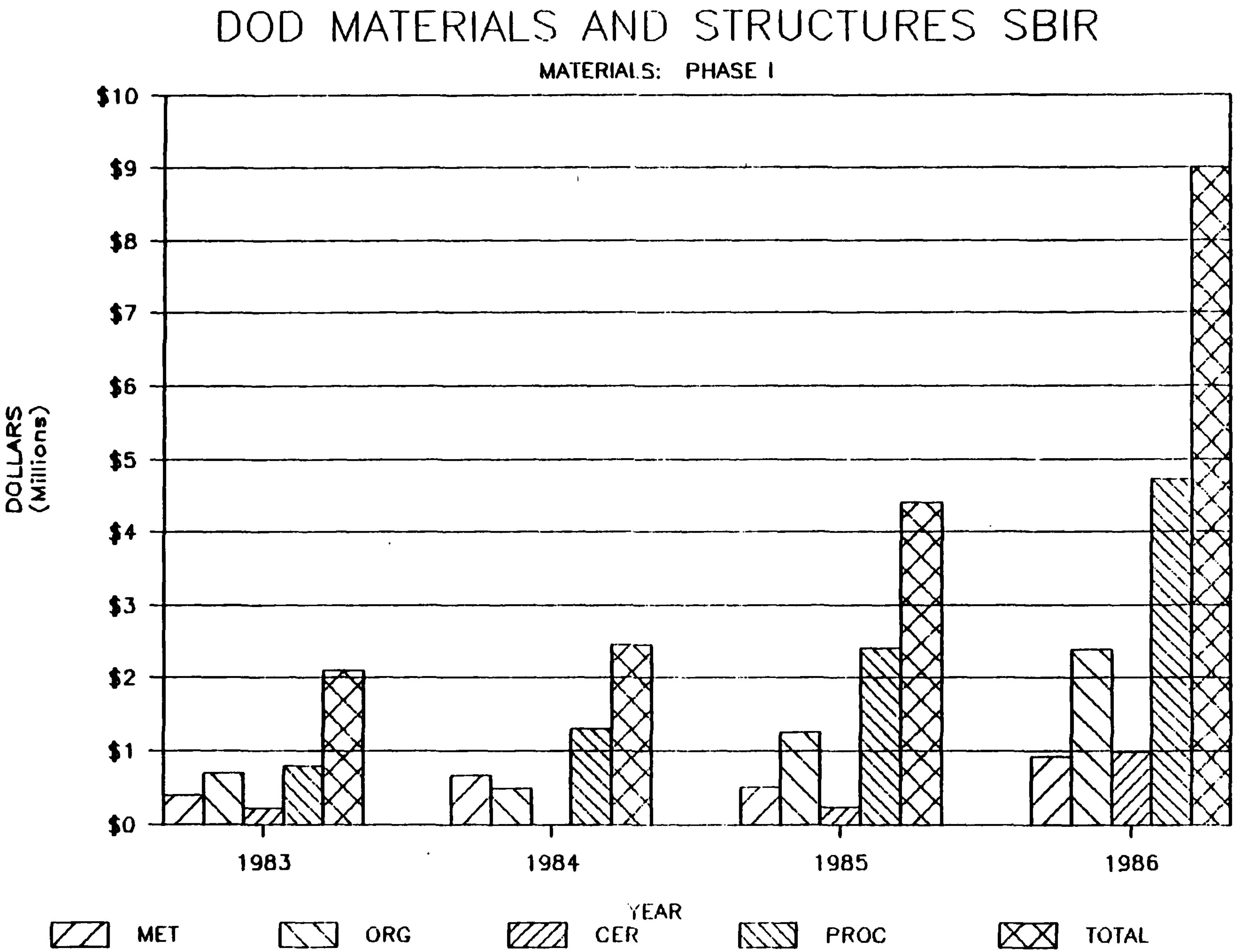
DOD MATERIALS AND STRUCTURES SBIR

MATERIALS & STRUCTURES ALLOCATION





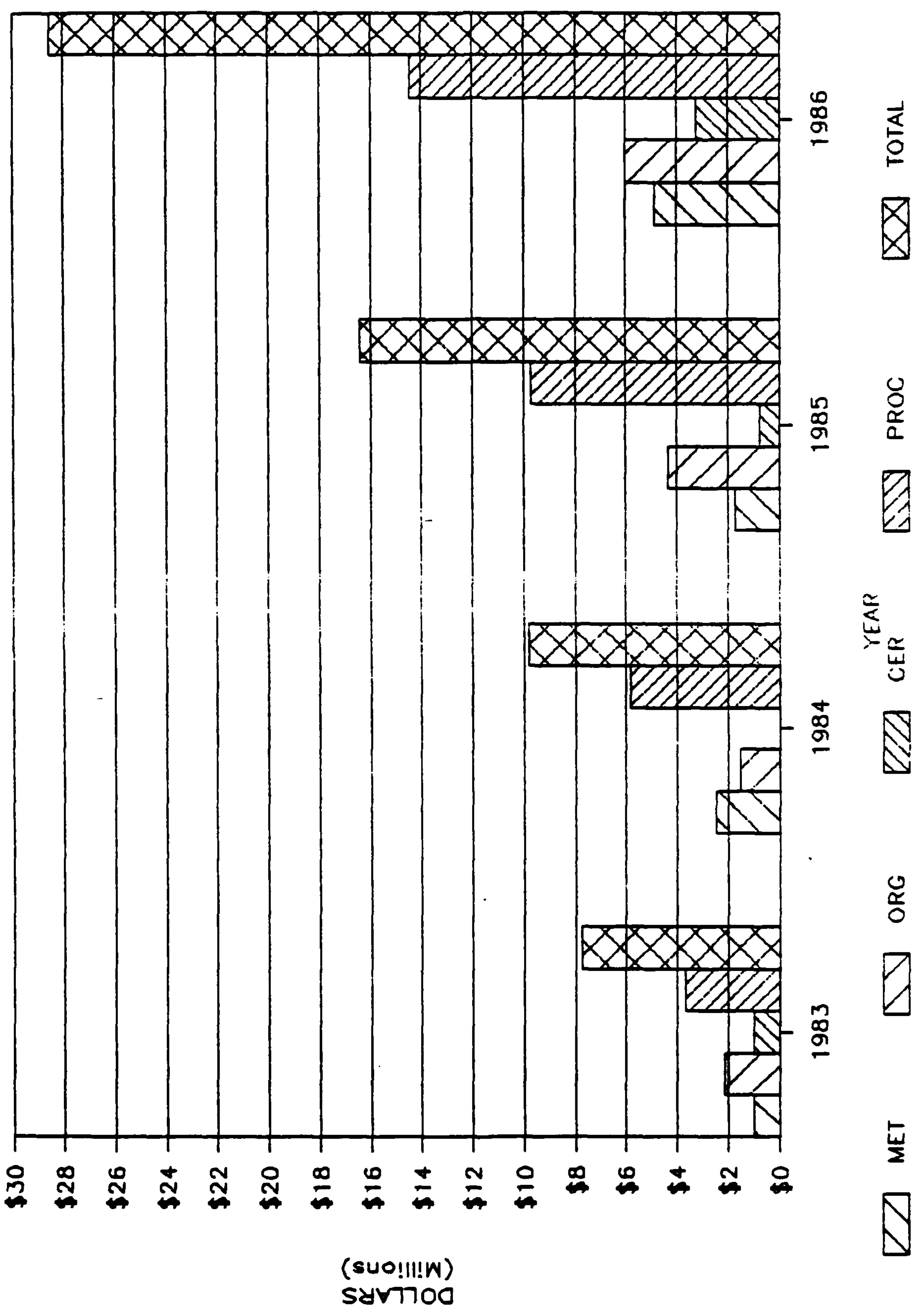
DOD MATERIALS AND STRUCTURES SBIR
TOTAL, PHASE I & PHASE II
$60
$50
$40
$30
$20
$10
$0
DOLLARS
(Millions)
1983
1984
1985
1986
YEAR
MAT
STRUC
NDE
TOTAL DOD

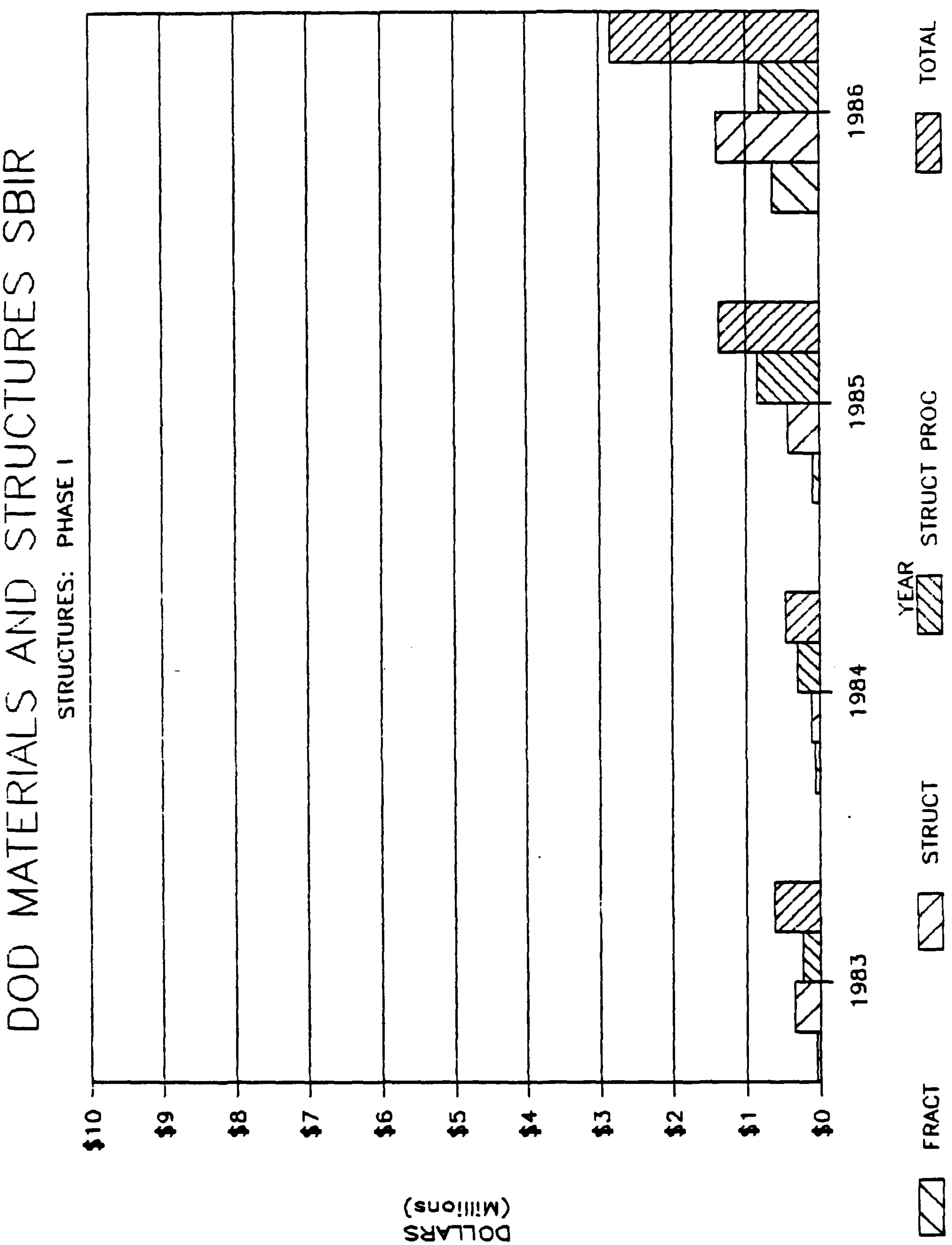


DOD MATERIALS AND STRUCTURES SBIR
MATERIALS: PHASE I
DOLLARS (Millions)
$10
$9
$8
$7
$6
$5
$4
$3
$2
$1
$0
1983
1984
1985
1986
YEAR
MET
ORG
CER
PROC
TOTAL

DOD MATERIALS AND STRUCTURES SBIR

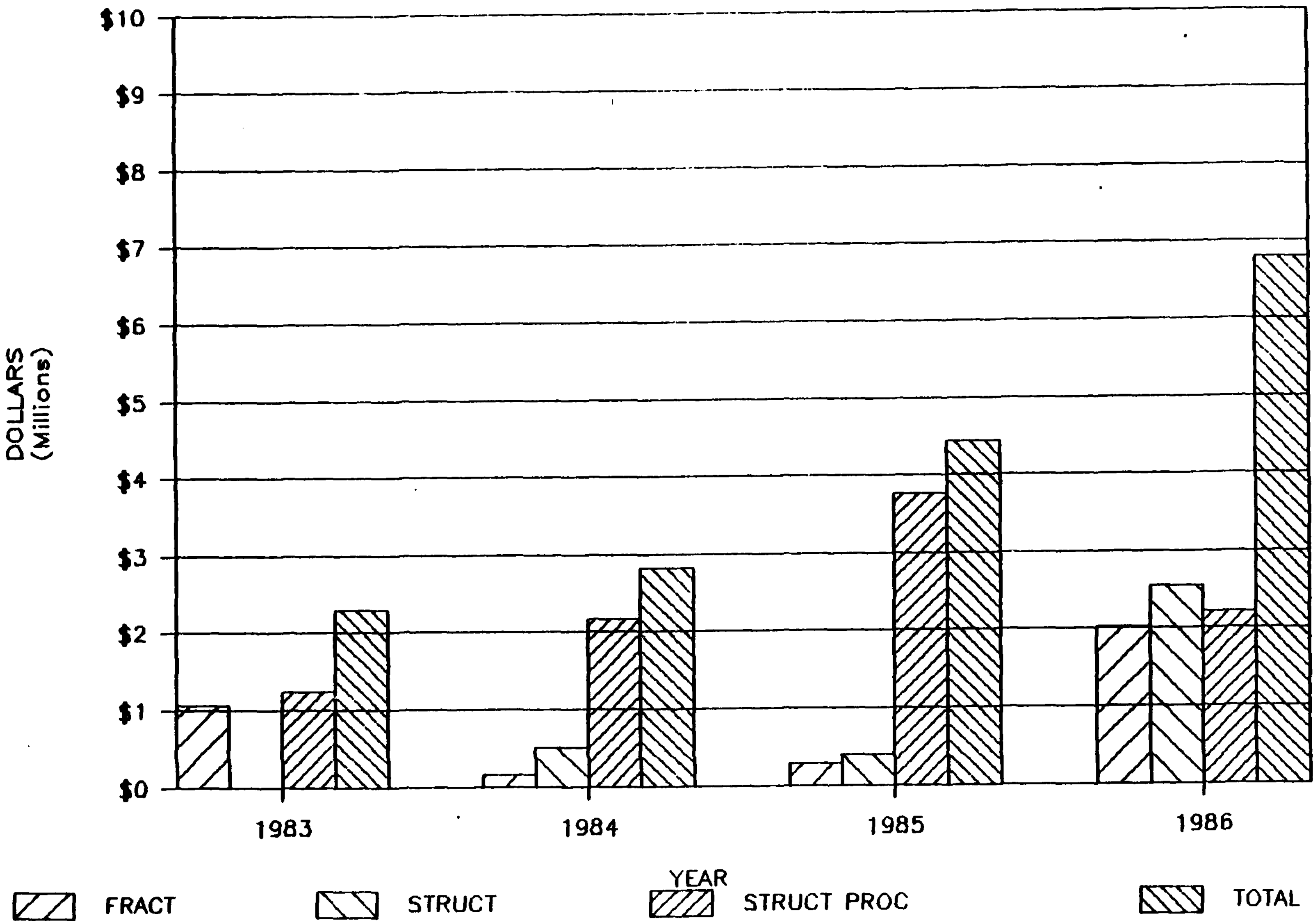
MATERIALS: PHASE II




DOD MATERIALS AND STRUCTURES SBIR
STRUCTURES: PHASE I
DOLLARS (Millions)
$0
$1
$2
$3
$4
$5
$6
$7
$8
$9
$10
1983
1984
1985
1986
YEAR
FRACT
STRUCT
STRUCT PROC
TOTAL

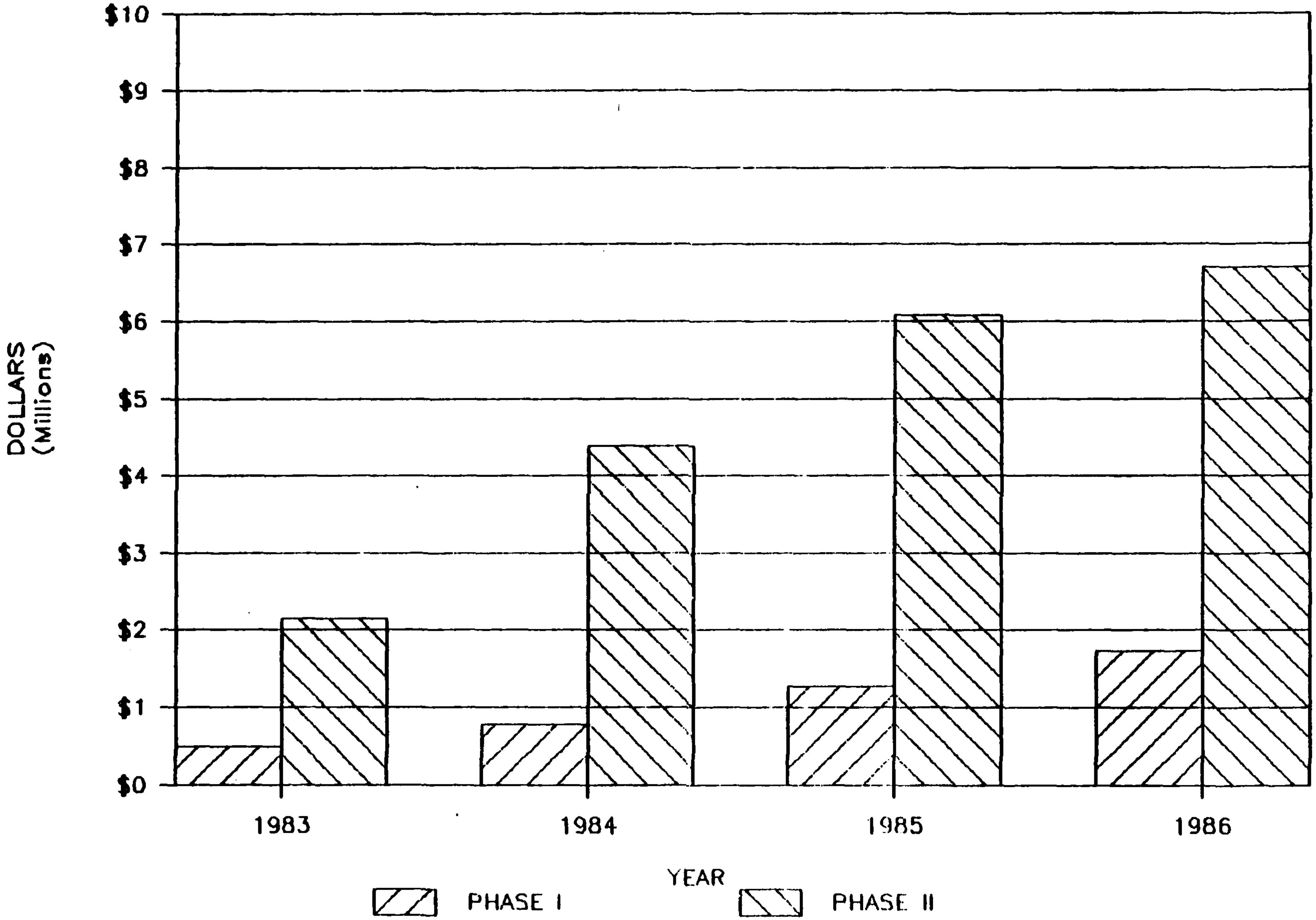
MATERIALS AND STRUCTURES SBIR

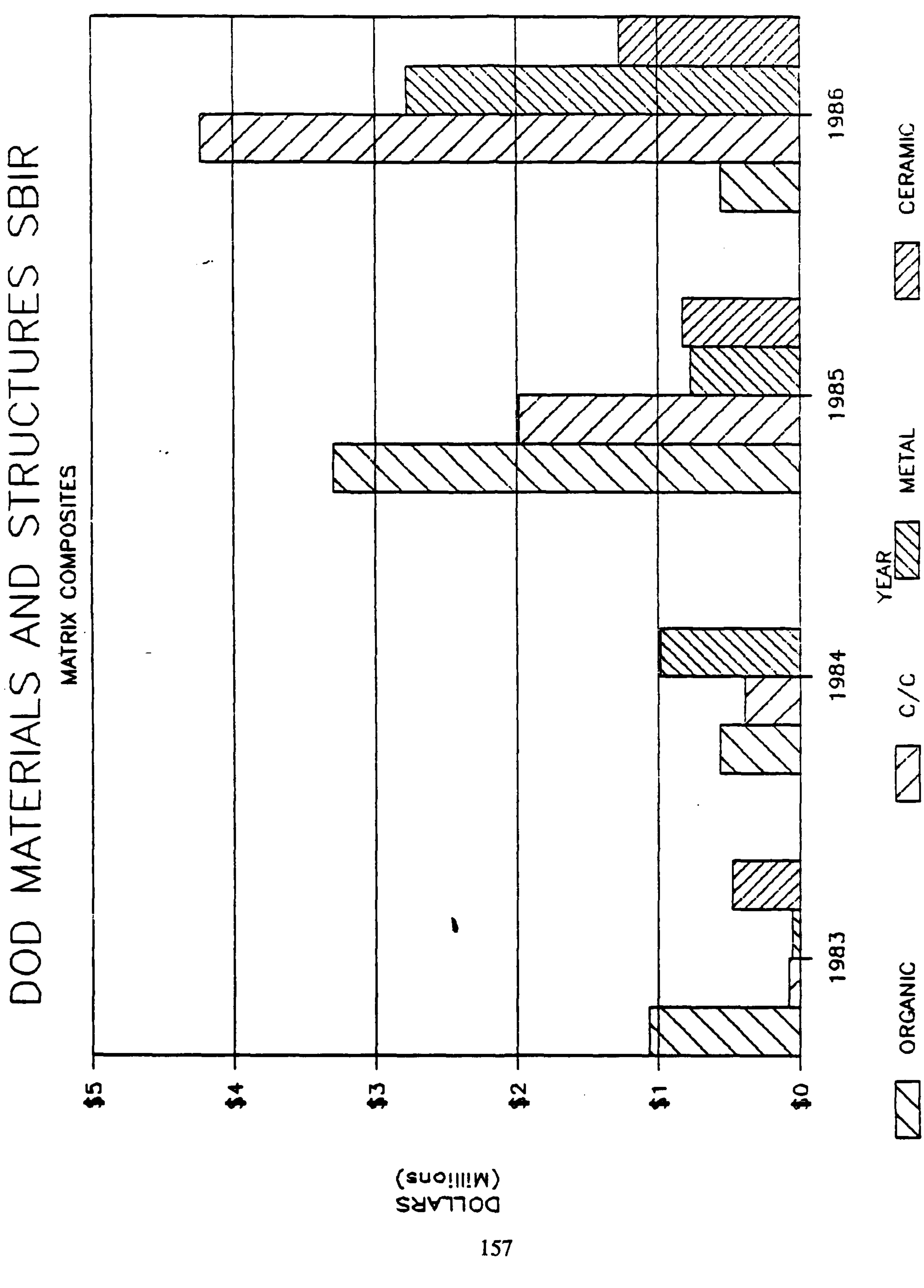
STRUCTURES: PHASE II

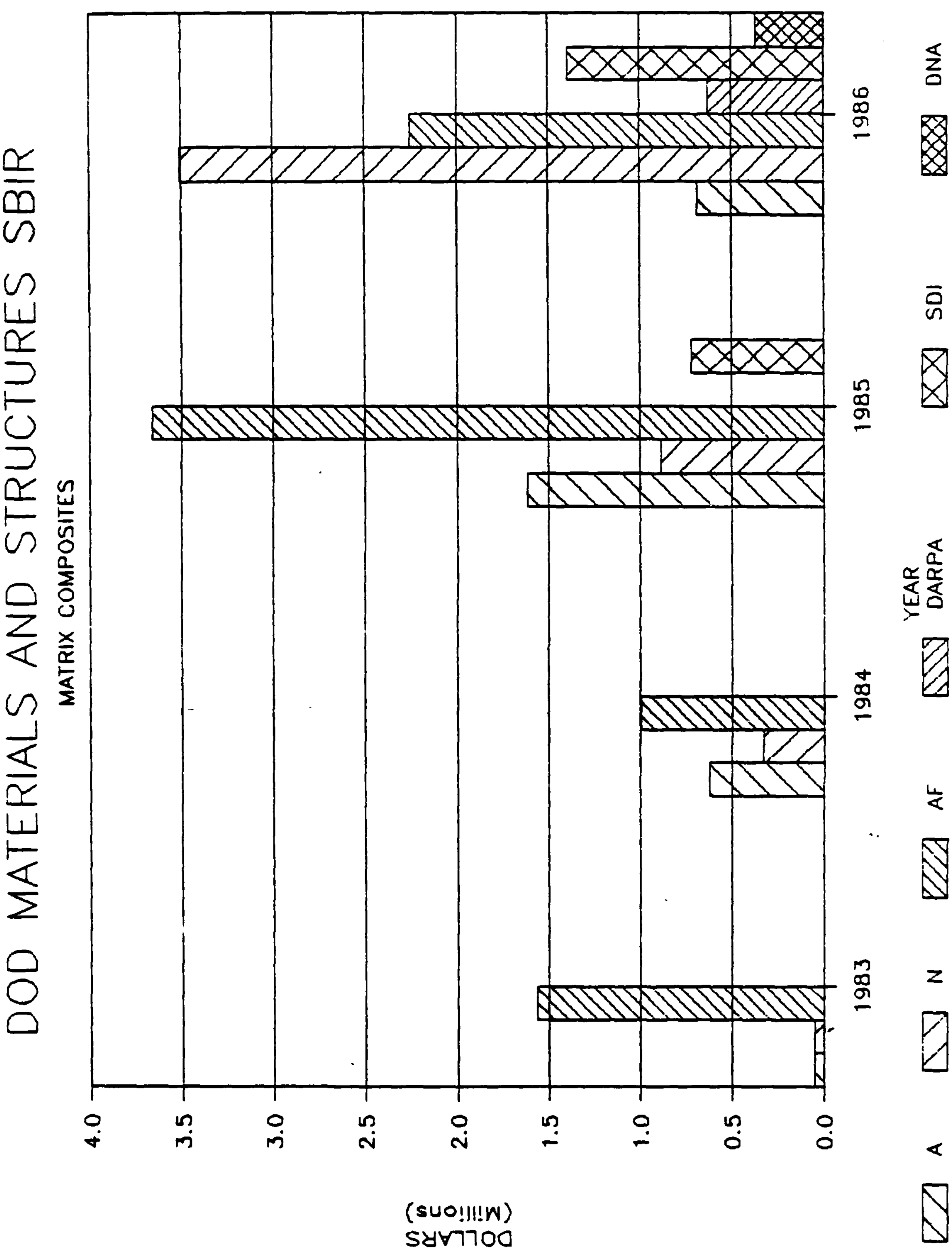


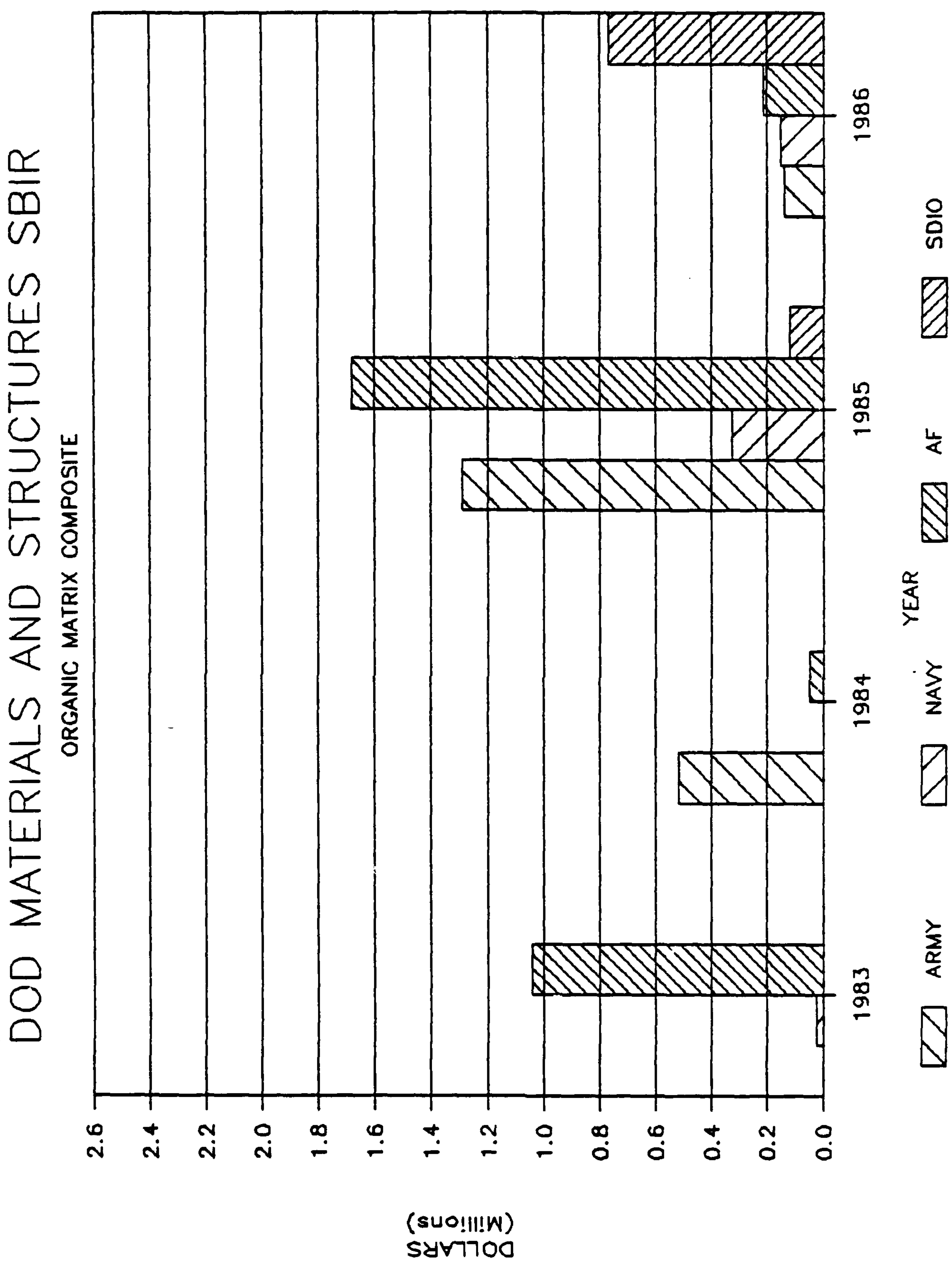
DOD MATERIALS AND STRUCTURES SBIR

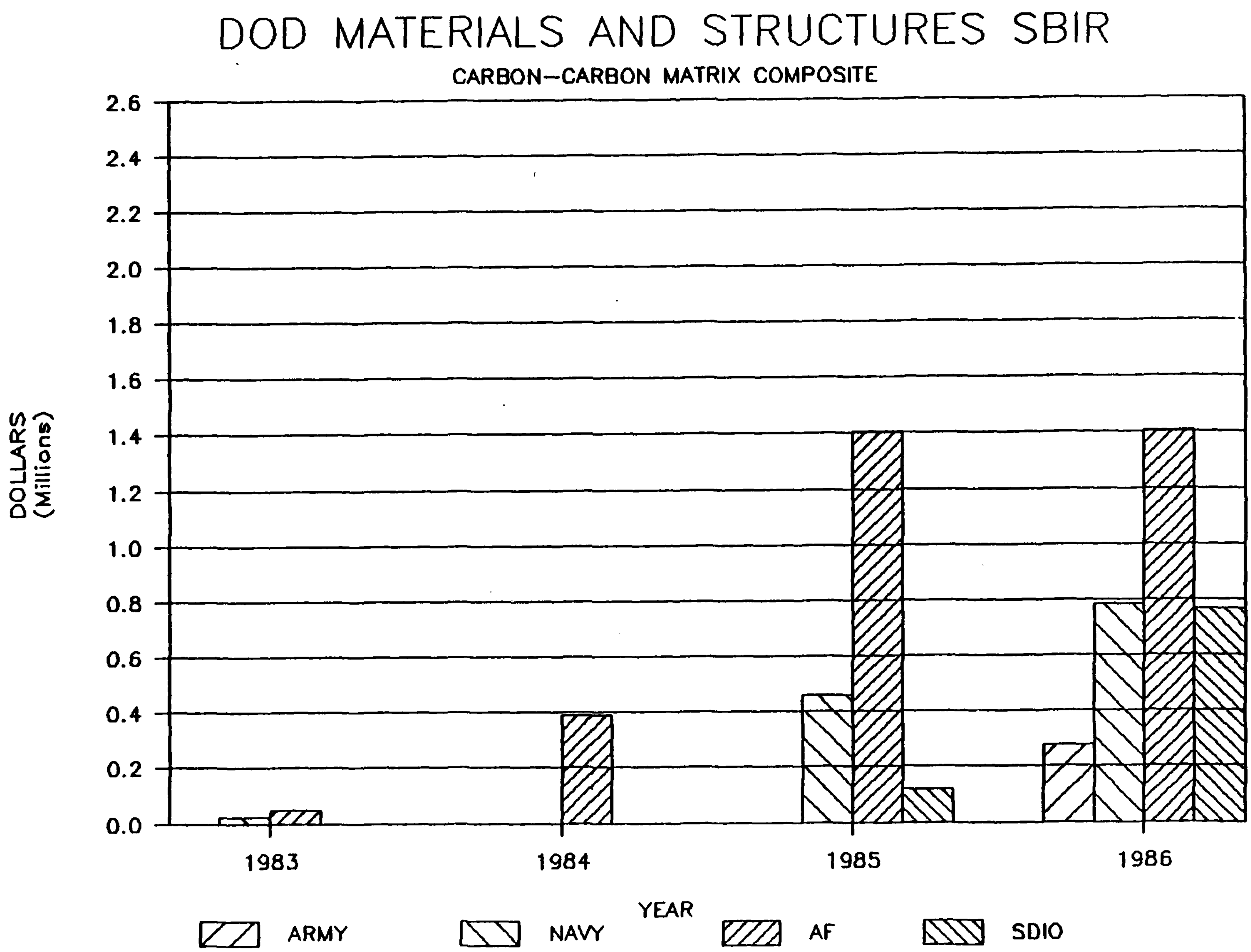
NDE




DOD MATERIALS AND STRUCTURES SBIR
MATRIX COMPOSITES
DOLLARS
(Millions)
$0
$1
$2
$3
$4
$5
1983
1984
1985
1986
YEAR
ORGANIC
C/C
METAL
CERAMIC


DOD MATERIALS AND STRUCTURES SBIR
MATRIX COMPOSITES
DOLLARS
(Millions)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1983
1984
1985
1986
YEAR
A
N
AF
DARPA
SDI
DNA

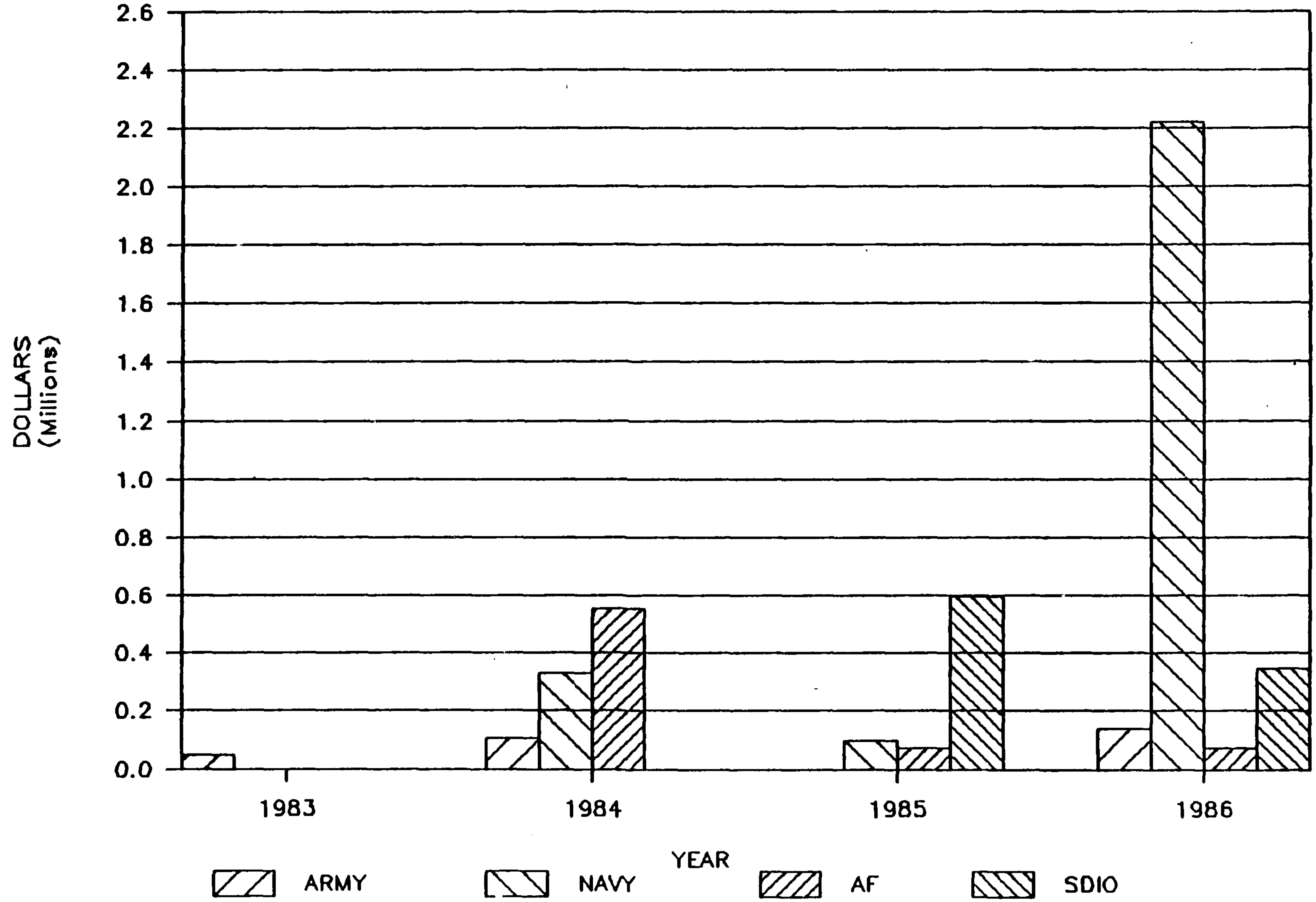

DOD MATERIALS AND STRUCTURES SBIR
ORGANIC MATRIX COMPOSITE
DOLLARS
(Millions)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1983
1984
1985
1986
YEAR
ARMY
NAVY
AF
SDIO

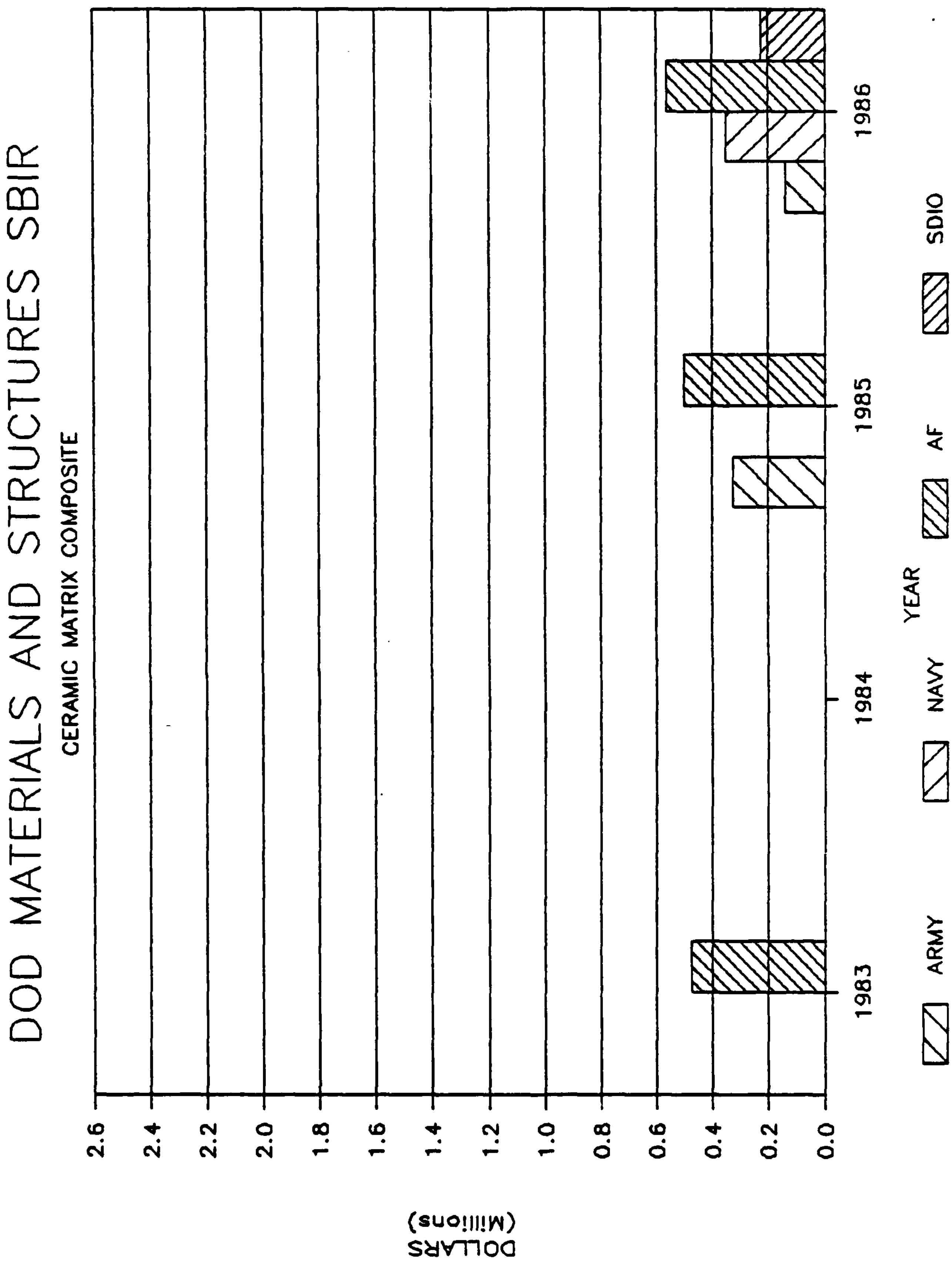


DOD MATERIALS AND STRUCTURES SBIR
CARBON—CARBON MATRIX COMPOSITE
DOLLARS (Millions)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1983
1984
1985
1986
YEAR
ARMY
NAVY
AF
SDIO

DOD MATERIALS AND STRUCTURES SBIR

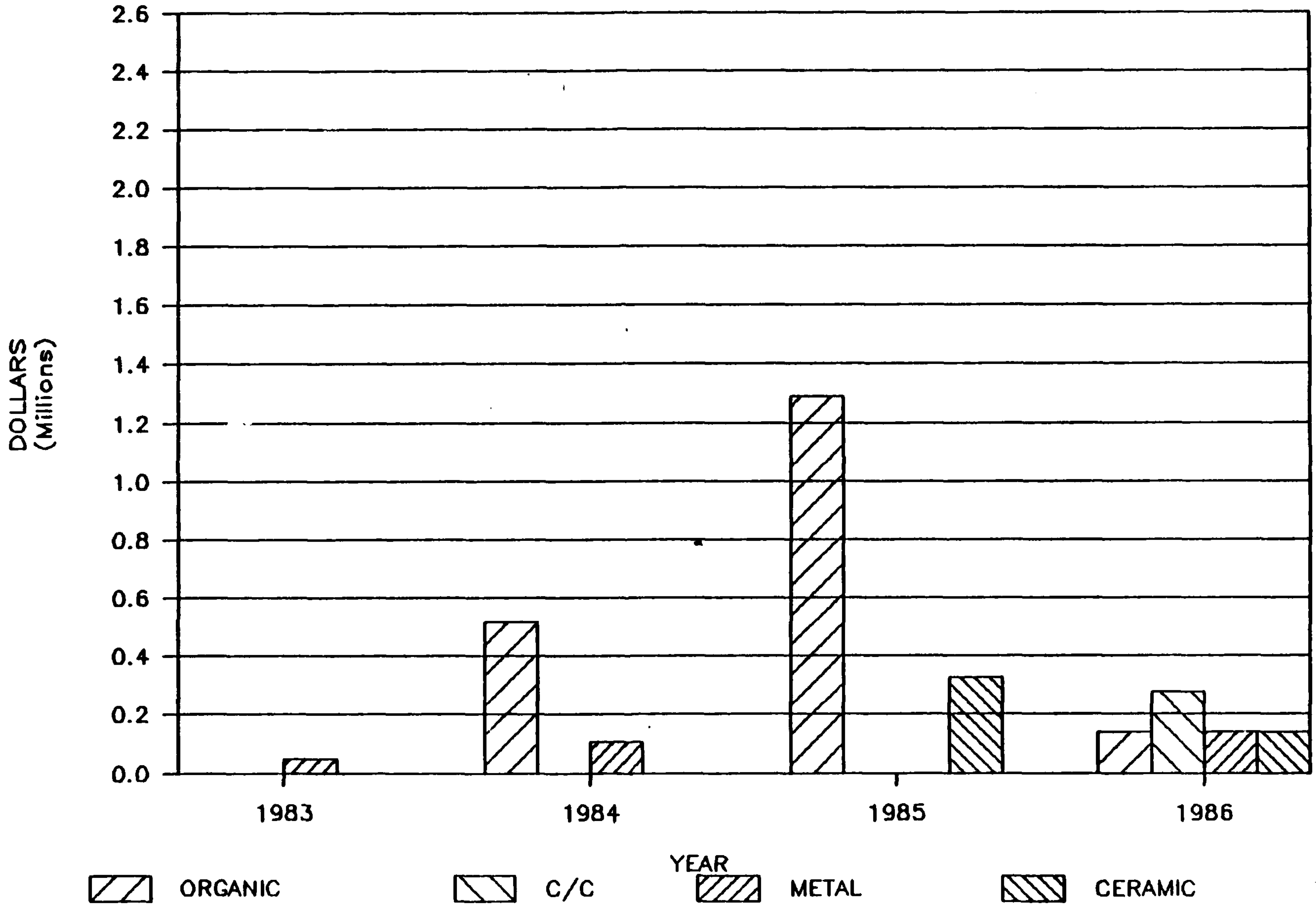
METAL MATRIX COMPOSITE

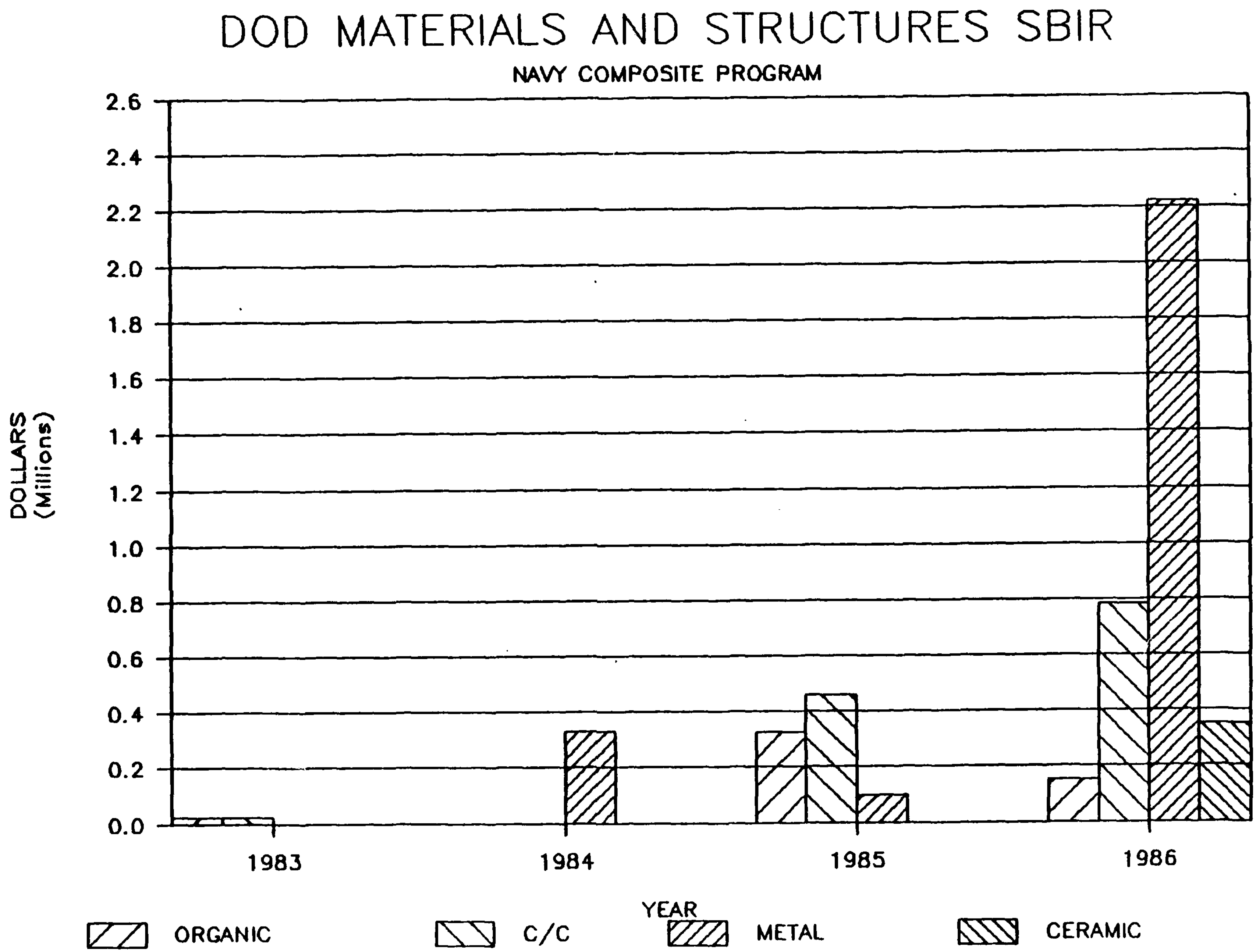



DOD MATERIALS AND STRUCTURES SBIR
CERAMIC MATRIX COMPOSITE
DOLLARS (Millions)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1983
1984
1985
1986
YEAR
ARMY
NAVY
AF
SDIO

DOD MATERIALS AND STRUCTURES SBIR

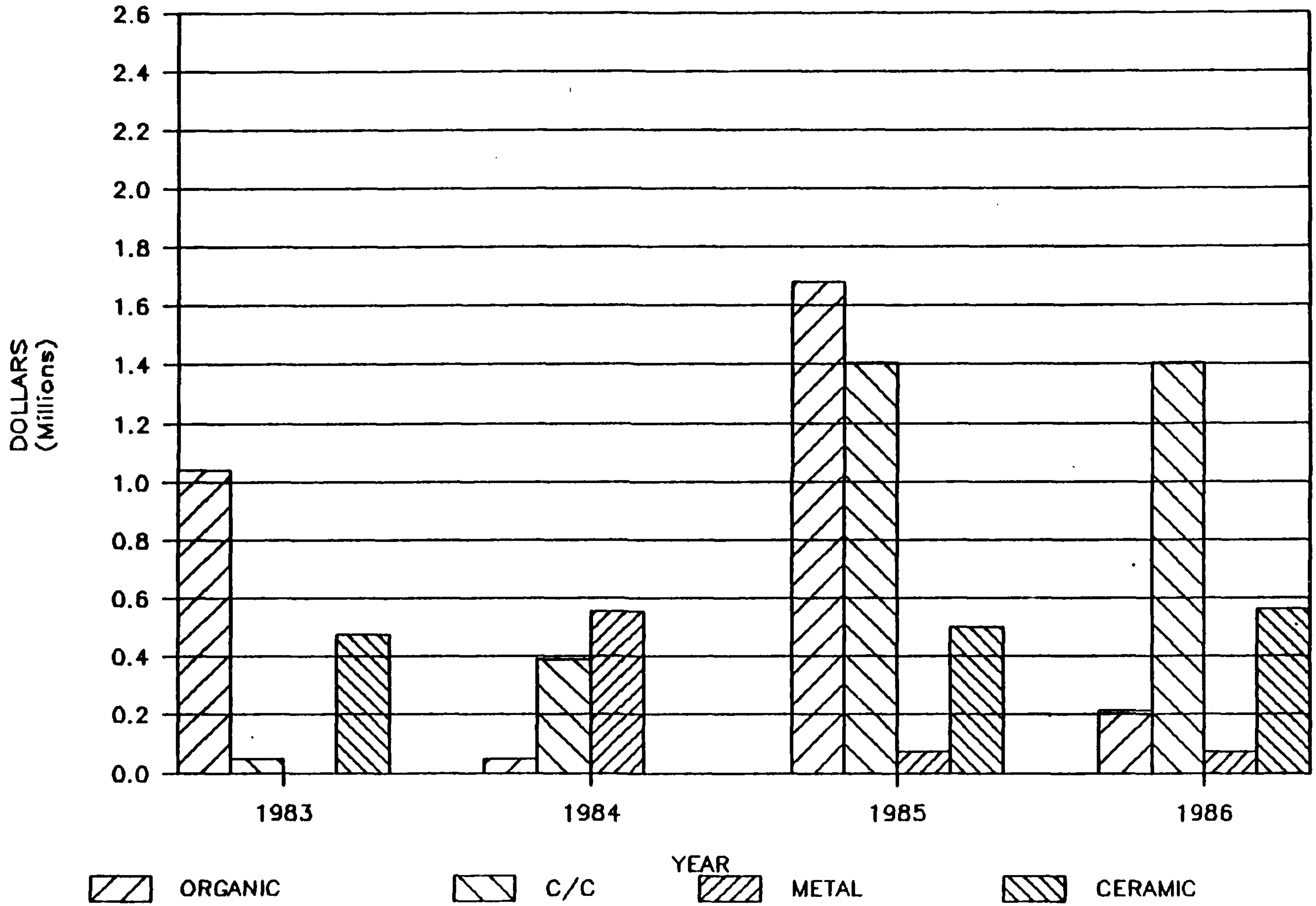
ARMY COMPOSITE PROGRAM

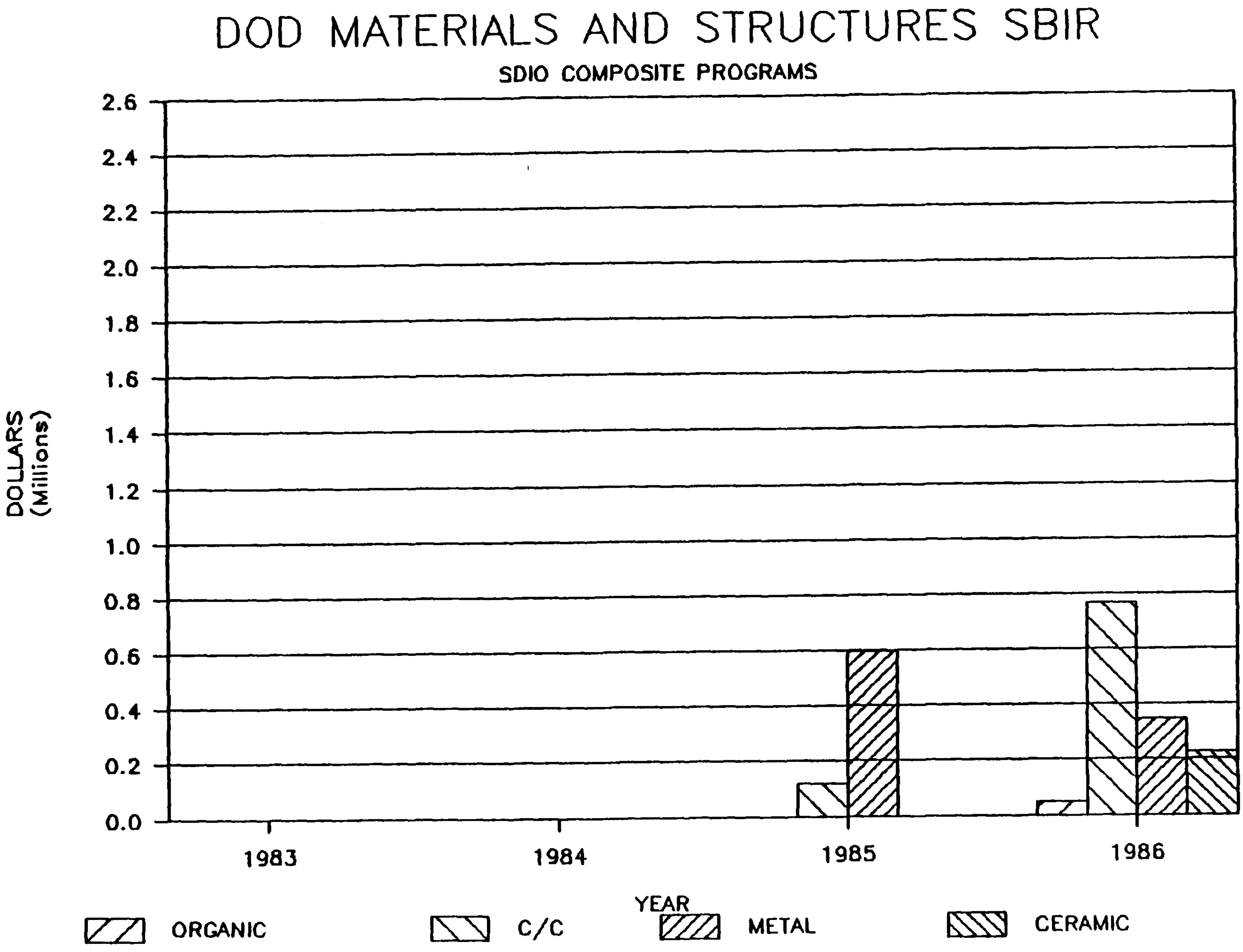



DOD MATERIALS AND STRUCTURES SBIR
NAVY COMPOSITE PROGRAM
DOLLARS (Millions)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1983
1984
1985
1986
YEAR
ORGANIC
C/C
METAL
CERAMIC

DOD MATERIALS AND STRUCTURES SBIR

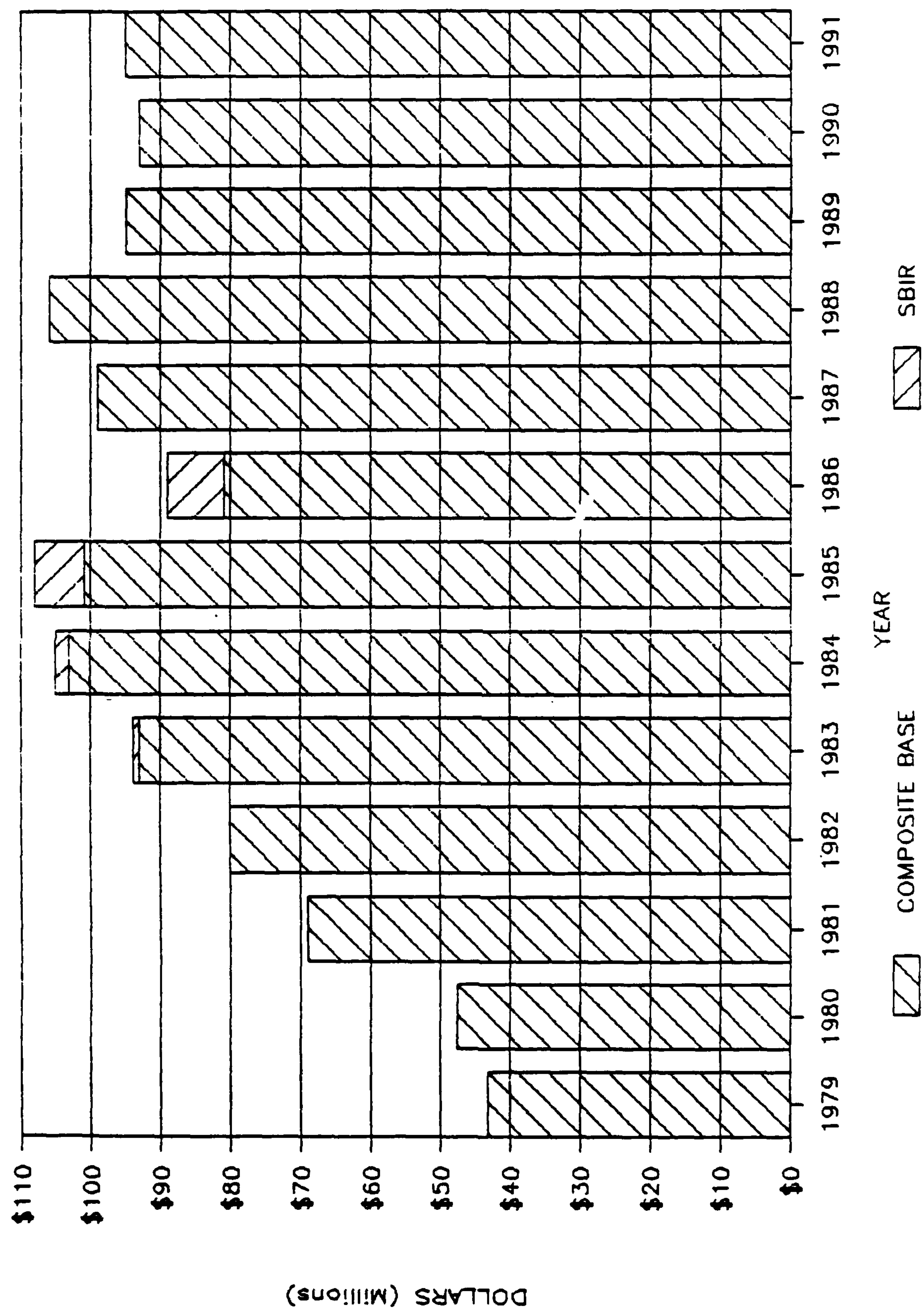
AIRFORCE COMPOSITE PROGRAMS

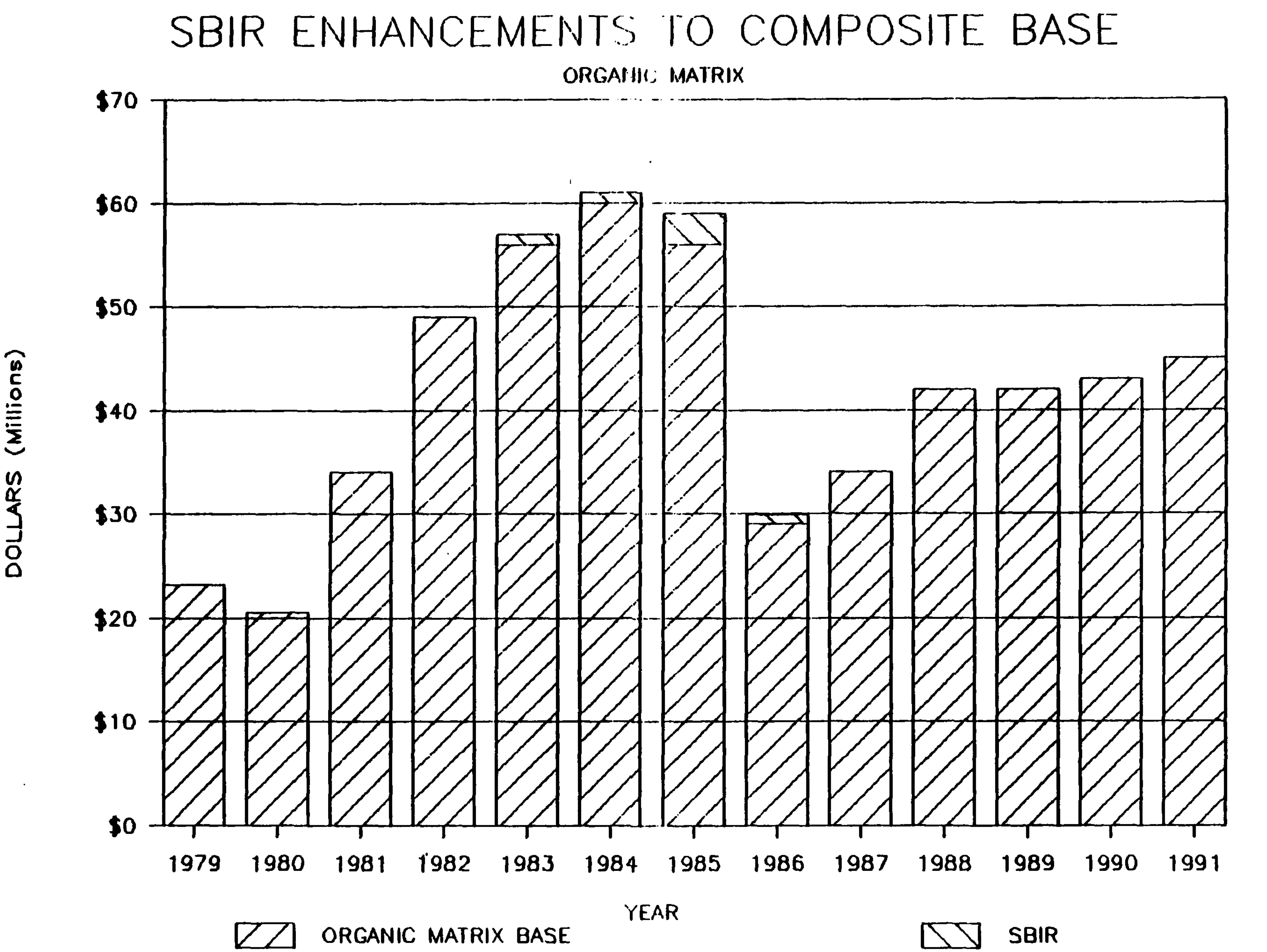


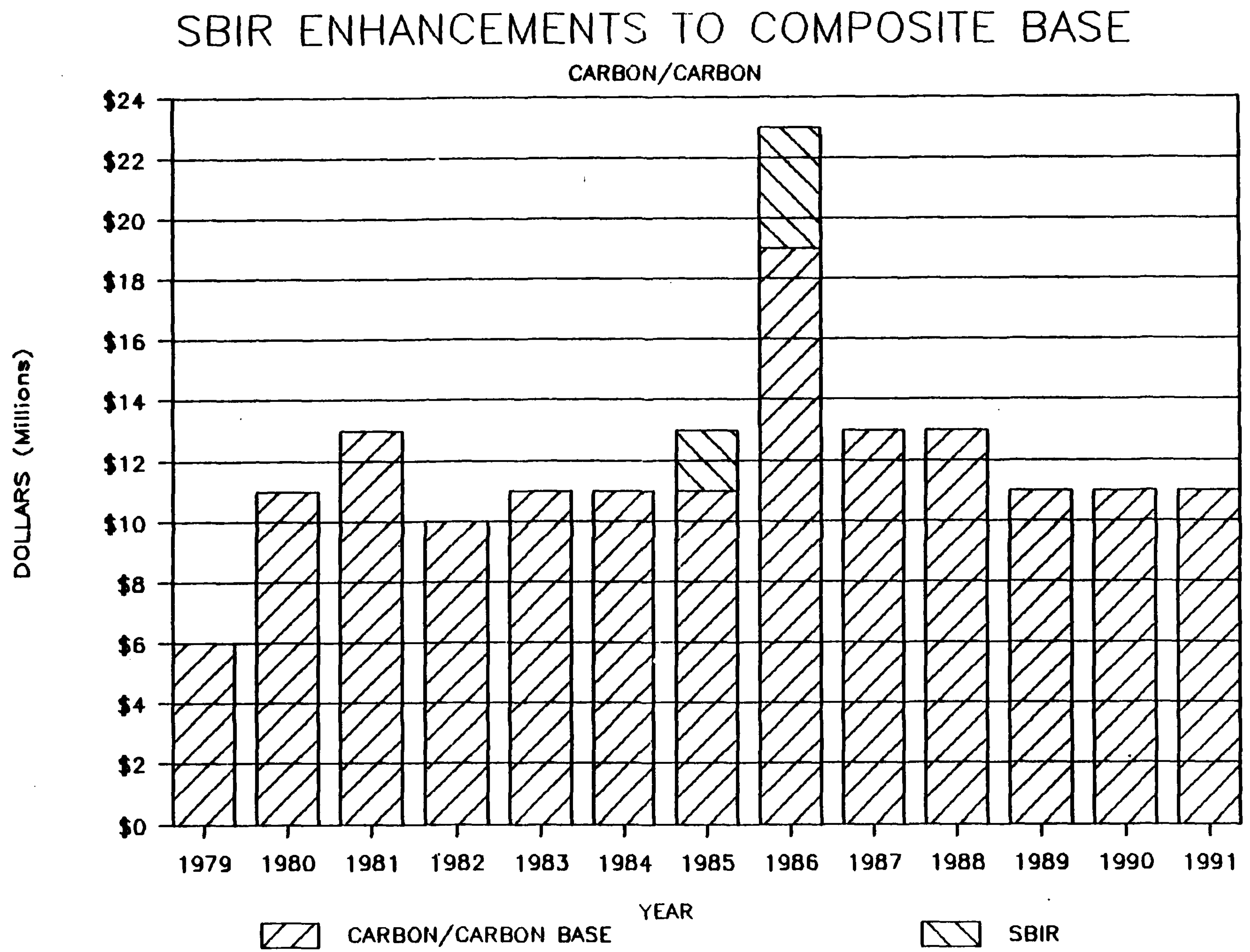


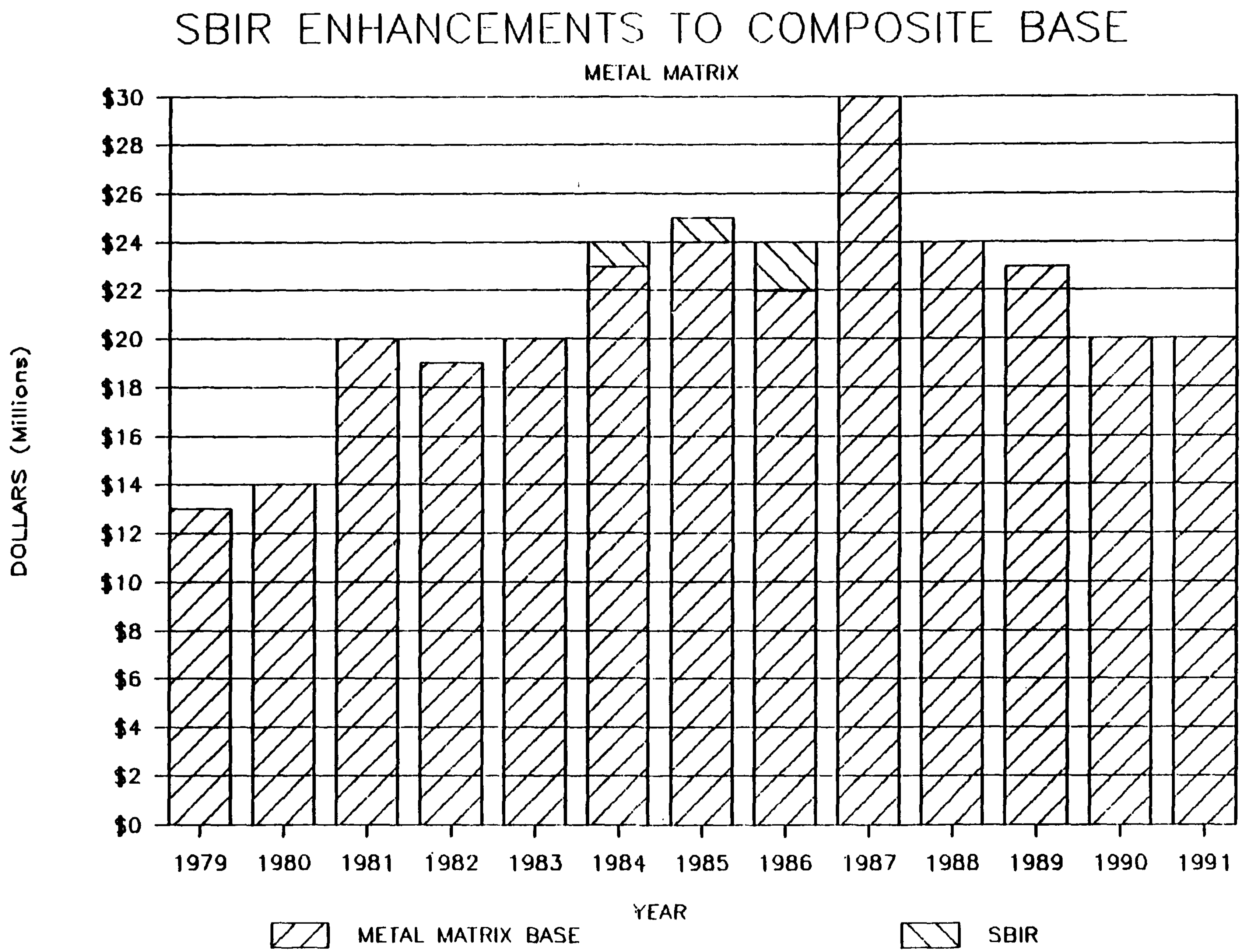
DOD MATERIALS AND STRUCTURES SBIR
SDIO COMPOSITE PROGRAMS
DOLLARS (Millions)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1983
1984
1985
1986
YEAR
ORGANIC
C/C
METAL
CERAMIC

SBIR ENHANCEMENTS TO COMPOSITE BASE




SBIR ENHANCEMENTS TO COMPOSITE BASE
ORGANIC MATRIX
$70
$60
$50
$40
$30
$20
$10
$0
DOLLARS (Millions)
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
YEAR
ORGANIC MATRIX BASE
SBIR

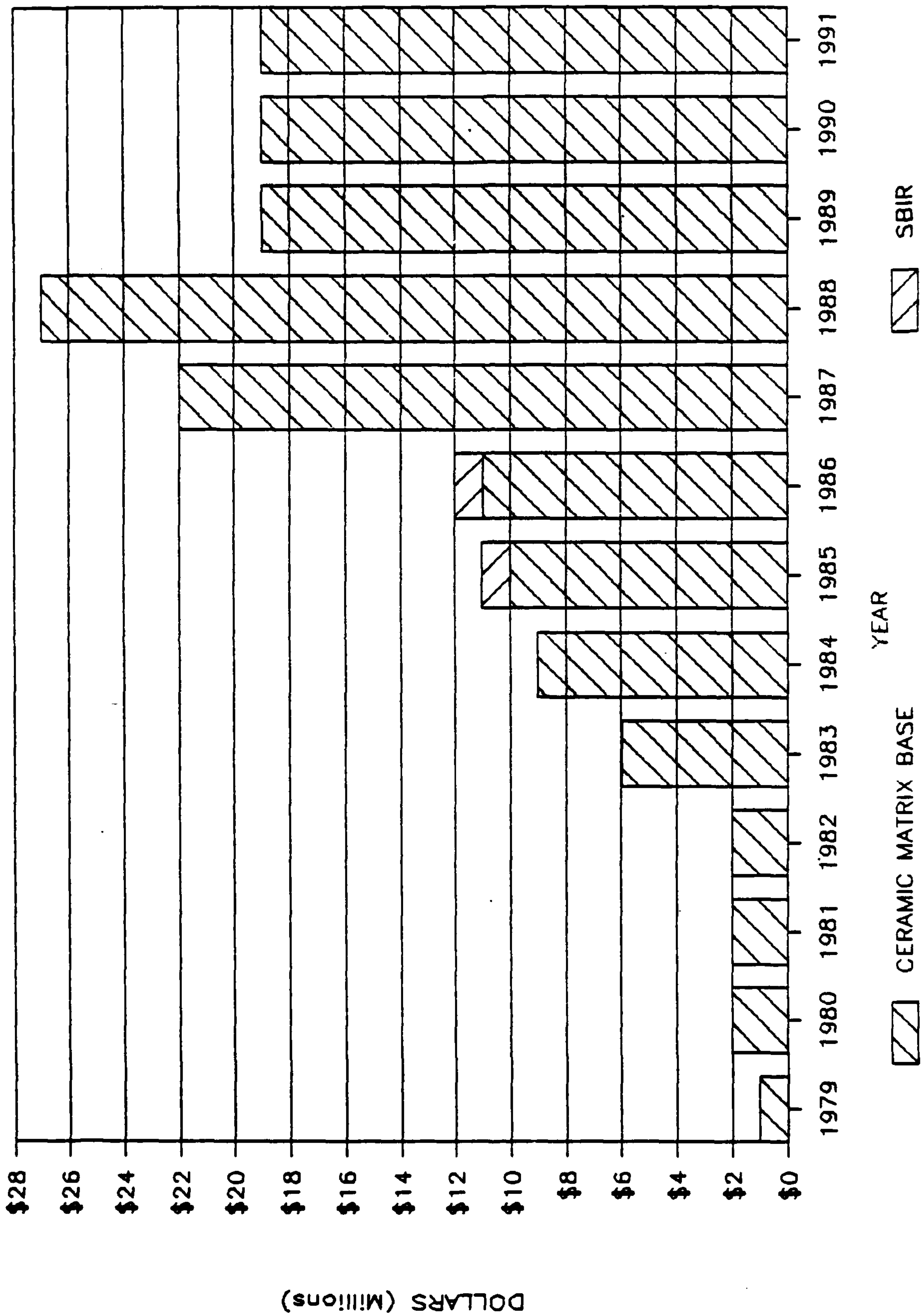

SBIR ENHANCEMENTS TO COMPOSITE BASE
CARBON/CARBON
DOLLARS (Millions)
$24
$22
$20
$18
$16
$14
$12
$10
$8
$6
$4
$2
$0
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
YEAR
CARBON/CARBON BASE
SBIR



SBIR ENHANCEMENTS TO COMPOSITE BASE
METAL MATRIX
DOLLARS (Millions)
$30
$28
$26
$24
$22
$20
$18
$16
$14
$12
$10
$8
$6
$4
$2
$0
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
YEAR
METAL MATRIX BASE
SBIR

SBIR ENHANCEMENTS TO COMPOSITE BASE

CERAMIC MATRIX



	CONTRACTOR	ORGANIC MATRIX	CARBON-CARBON	METAL MATRIX	CERAMIC MATRIX	FY	PHASE	SER-VICE	REMARKS
81	ABARTS	24861	24861	0	0	83	I	N	LT WEIGHT LAUNCHERS
326	ABARTS	25000	25000	0	0	85	I	AF	SYSTEM FOR COMPOSITE REPAIR
329	ABARTS	25000	25000	0	0	85	I	AF	ULTRASONIC INSPECTION OF COMPOSITE
795	ABARTS	0	500000	0	0	86	II	N	ASSESST OF PLASTIC FOR SUBMARINES STRUCTURES
256	ADV COMPOSITE PRODUCT	83783	0	0	0	85	I	A	DEV THERMOPLASTIC COMPOSITE BRIDGE MTRS
303	ADV COMPOSITE PRODUCT	74600	0	0	0	85	I	AF	CONTINUOUS HEATED ROLL FORMING OF THERMOPLASTIC
404	ADV COMPOSITE PRODUCT	642000	0	0	0	85	II	A	DEV TOUGH THERMOPLASTIC COMPOSITE
425	ADV COMPOSITE PRODUCT	406650	0	0	0	85	II	AF	CONTINUOUS HEATED ROLL FORMING OF THERMOPLASTIC
472	ADV COMPOSITE PRODUCT	0	90000	0	0	86	I	A	THERMOPLASTIC COMPOSITE MTRL FORMS
511	ADV COMPOSITE PRODUCT	0	84637	0	0	86	I	AF	NOVEL GRAPHITE THERMOPLASTIC YARN
783	ADV COMPOSITE PRODUCT	0	497179	0	0	86	II	AF	NOVEL GRAPHITE THERMOPLASTIC YARN
849	ADV COMPOSITE PRODUCT	0	81174	0	0	87	I	A	CONFORMAL THERMOPLASTIC COMPOSITE STRUCTURE
1056	ADV COMPOSITE PRODUCT	92378	0	0	0	87	I	SDIO	THERMOPLASTIC COMPOSITES FOR SPACE
633	ADV MATERIALS LAB	0	0	49784	0	86	I	N	BEHAVIOR OF MMC AT CRYOGENIC TEMPERATURES
808	ADV MATERIALS LAB	0	0	151563	0	86	II	N	BEHAVIOR OF MMC AT CRYOGENIC TEMP
875	ADV MATERIALS LAB	0	0	50000	0	87	I	DARPA	MAGNESIUM COMPOSITES FOR HYDROGEN STORAGE
648	ADV REFRACTORY TECH	0	0	0	48658	86	I	N	MTRLS FOR CERAMIC ARMOR
957	AM SCIENCES & ENGR	0	49990	0	0	87	I	AF	OPTICAL IMAGING OF CARBON-CARBON COMPOSITES
393	AMERICAN RESEARCH	0	69721	0	0	85	I	SDIO	PLASMA DEPOSITION AND LASER DENSIFICATION/CARBON
597	AMERICAN RESEARCH	0	66759	0	0	86	I	DARPA	MICROWAVE EVALUATION OF CARBON-CARBON COMPOSITES
791	AMERICAN RESEARCH	0	499743	0	0	86	II	DARPA	MICROWAVE EVALUATION OF CARBON-CARBON COMPOSITES
96	AMERICOM	0	0	0	474300	83	II	AF	CERAMIC MATRIX COMPOSITES
590	ANAMET LABS	49875	0	0	0	86	I	AF	STUDY RAPID THERMAL LOADING OF COMPOSITE STRUCTURES
108	ANDRULIS RESEARCH	498950	0	0	0	83	II	AF	FASIL POLYMERS R&D
1078	APPLIED SCIENCE	0	74178	0	0	87	I	SDIO	LIGHTWEIGHT COMPOSITES
1088	APPLIED SCIENCES	0	82061	0	0	87	I	SDIO	GRAPHITE FIBERS FOR ELECTROMAGNETIC RAILGUN
709	ARDES ENTERPRICES	0	0	74260	0	86	I	SDIO	COMPOSITE FILAMENT FOR DAMPED COMPOSITES STRUCTURES
474	AUTOMATED DYNAMICS	0	50000	0	0	86	I	A	GRAPHITE WITH THERMOPLASTIC WELDING HEAD
915	BIO-TECH RESOURCES	12500	12500	12500	12500	87	I	AF	RESINS FOR COMPOSITE
307	CAMBRIDGE ISOTOPE	41085	0	0	0	85	I	AF	SYNTHESIS OF NEW POLYMERS
999	CASTLE PT RSCH TECH	6162	6162	6162	6162	87	I	N	FAILURE CRITERIA FOR COMPOSITE MATERIALS
1154	CASTLE PT RSCH TECH	92267	92267	92267	92267	87	II	N	FAILURE CRITERIA FOR COMPOSITE MATERIALS
572	CASTLE TECHNOLOGY	0	48329	0	0	86	I	AF	COATINGS FOR CARBON COMPOSITE MATERIALS
684	CASTLE TECHNOLOGY	0	0	49304	0	86	I	N	CORROSION OF MMC
344	CERAMATEC	0	0	0	49889	85	I	DOE	CHARACTERIZATION OF CERAMICS MATRIX WHISKER COMPOSITE
1011	CERAMATEC	12473	12473	12473	12473	87	I	N	COMPOSITE MATERIALS FOR ADV HYPERSONIC VEHICLES
1025	CERAMATEC	0	0	0	49971	87	I	N	FRACTOGRAPHY OF SILICON NITRIDE
1001	CONCEPT ANALYSIS	12450	12450	12450	12450	87	I	N	FRACTURE TOUGHNESS OF FIBER-REINFORCED COMPOSITES
387	CORDEC	0	0	49880	0	85	I	N	BOND QUALITY DEFINITION IN GRAPHITE/ALUMINUM COMPOSITES
392	CORDEC	0	49003	0	0	85	I	SDIO	ULTRA-THIN GRAPHITE/COPPER METAL MATRIX
697	CORDEC	0	0	49828	0	86	I	SDIO	METAL MATRIX COMPOSITE BARREL MATERIAL
700	CORDEC	0	0	49891	0	86	I	SDIO	SURVIVABILITY OF METAL MATRIX COMPOSITES IN SPACE

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	CONTRACTOR	ORGANIC MATRIX	CARBON-CARBON	METAL MATRIX	CERAMIC MATRIX	FY	PHASE	SERVICE	REMARKS
710	CORDEC	0	0	49899	0	86	I	SDIO	TITANIUM COMPOSITE STRUCTURAL ELEMENTS
880	CORDEC	0	0	49996	0	87	I	DARPA	HIGH TEMP METAL COMPOSITES FOR HYPERSONIC
1100	CORDEC	0	0	49981	0	87	I	SDIO	SUPER CONDUCTIVE COMPOSITES FOR RAIL & PLASMA GAINS
319	CTL	46376	0	0	0	85	I	AF	TRANS-LAMINAR REINFORCEMENT ORGANIC MATRIX
130	CUMAGA CORP.	49334	0	0	0	84	I	A	OPTIMIZE WEAVE PROCESS IN COMPOSITES
270	DENANET TECHNO	0	0	0	48393	85	I	A	DUCTILE ALLOY ENCAPSULATED CERAMIC ARMOR
1036	DWA COMPOSITE SPECIALIST	0	25014	25014	0	87	I	N	MATRIX ALLOY DEVELOPMENT
1093	DWA COMPOSITE SPECIALIST	0	0	49987	0	87	I	SDIO	HYBRID METAL MATRIX COMPOSITES FOR SPACE STRUCTURE
1099	DWA COMPOSITE SPECIALIST	0	0	50260	0	87	I	SDIO	JOINTING CONCEPTS FOR METAL MATRIX COMPOSITE TRUSS
225	DWA COMPOSITE SPECIALIST	0	0	454610	0	84	II	AF	HIGH TEMP METAL MATRIX COMPOSITES
394	DWA COMPOSITE SPECIALIST	0	0	49897	0	85	I	SDIO	MAGNESIUM-GRAPHITE HYBRID COMPOSITE PLATE
651	DWA COMPOSITE SPECIALIST	0	0	49928	0	86	I	N	HYBRID MMC MTRLS FOR THERMAL MIS-MATCH
659	DWA COMPOSITE SPECIALIST	0	24989	24989	0	86	I	N	COMBINING MTRL FOR HIGH SPECIFIC MODULUS & STRENGTH
702	DWA COMPOSITE SPECIALIST	0	0	92789	0	86	I	SDIO	THERMO-MECHANICAL RESISTANT COMPOSITES
802	DWA COMPOSITE SPECIALIST	0	0	498581	0	86	II	N	HYBRID MMC FOR DISTORTION CONTROL
913	DWA COMPOSITE SPECIALIST	0	0	47684	0	87	I	AF	METAL MATRIX FOR GRAPHITE/ALUMIN STRUCTURES
997	DWA COMPOSITE SPECIALIST	0	0	25011	25011	87	I	N	MICROSTRUCTURAL EFFECTS IN METAL MATRIX COMPOSITES
1062	DWA COMPOSITE SPECIALIST	0	0	49967	0	87	I	SDIO	METAL MATRIX FOR SPACE STRUCTURES
203	DYNAMET TECHNOLOGY	0	0	47847	0	85	I	N	PRODUCE TITANIUM MATRIX COMPOSITES VIA POWDER TECH.
235	DYNAMET TECHNOLOGY	0	0	280508	0	85	II	N	TITANIUM MATRIX COMPOSITES
409	DYNAMET TECHNOLOGY	0	0	0	277508	85	II	A	ENCAPSULATED CERAMIC ARMOR
395	EIC LAB.	0	0	49894	0	85	I	SDIO	METAL-METAL MICROFILAMENTARY COMPOSITES FOR HIGH CURRENT
459	EIC LAB.	0	0	498000	0	85	II	SDIO	METAL-METAL MICROFILAMENTARY COMPOSITES FOR HIGH CURRENT
128	ELECTROMAGNETIC SCIENCES	0	0	55044	0	84	I	A	FERRITE COMPOUNDS AS MICROWAVE ABSORBERS
257	ELFIN	65036	0	0	0	85	I	A	COMPOSITE SHELL BRIDGE DECK
1067	EMEC CONSULTANTS	0	0	49380	0	87	I	SDIO	ALUMINUM-CARBON COMPOSITE MATERIALS
711	ENERGY MTRLS RESEARCH	0	0	0	75209	86	I	SDIO	FLEXIBLE CERAMIC COMPOSITES
1052	ERG	0	0	0	57972	87	I	SDIO	NET SHAPE CERAMIC MATERIALS
136	FIBER MATERIALS	0	49860	0	0	84	I	AF	IMPROVED HYBRID FIBER CARBON-CARBON COMPOSITES
230	FIBER MATERIALS	0	291061	0	0	84	II	AF	COMPOSITE COMPATIBILITY WITH OXIDATION RESIST COATING
311	FIBER MATERIALS	0	48889	0	0	85	I	AF	FIBEROUS CARBON COMPOSITES
442	FIBER MATERIALS	0	0	0	499031	85	II	AF	CERAMIC COMPOSITES FOR ADV SOLID ROCKET MOTOR
581	FIBER MATERIALS	0	48249	0	0	86	I	AF	COMPOSITE FASTENERS FOR CARBON/CARBON STRUCTURES
712	FIBER MATERIALS	0	49956	0	0	86	I	SDIO	DAMPED CHARACTERISTICS OF CARBON-CARBON COMPOSITES
713	FIBER MATERIALS	0	49999	0	0	86	I	SDIO	DAMPED CARBON-CARBON COMPOSITES
987	FIBER MATERIALS	0	24983	0	24983	87	I	N	DEV HIGH STRENGTH CARBON & CERAMIC MATRIX COMPOSITE
1087	FIBER MATERIALS	12344	12344	12344	12344	87	I	SDIO	ULTRALIGHT BRADED CONE
591	FLOW RESEARCH	49836	0	0	0	86	I	AF	STUDY THERMAL PULSING OF COMPOSITE STRUCTURES
592	FLOW RESEARCH	49730	0	0	0	86	I	AF	STUDY THERMAL PULSING OF COMPOSITE STRUCTURES
618	FLOW RESEARCH	0	0	0	49964	86	I	DOE	CERAMIC-CERAMIC COMPOSITES
986	FLOW RESEARCH	0	0	0	49955	87	I	N	DEV HIGH TEMP CERAMICS
1000	FLOW RESEARCH	24987	0	24987	0	87	I	N	CHARACTERIZATION OF ADV COMPOSITE MATERIALS

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	CONTRACTOR	ORGANIC MATRIX	CARBON-CARBON	METAL MATRIX	CERAMIC MATRIX	FY	PHASE	SERVICE	REMARKS
1157	FLOW RESEARCH	248388	0	248388	0	87	II	N	CHARACTERIZATION OF ADV COMPOSITES MATERIALS
103	FOSTER-MILLER	494028	0	0	0	83	II	AF	POLYMERS FOR SPACE STRUCTURES
258	FOSTER-MILLER	72389	0	0	0	85	I	A	FIBER REINFORCED THERMOPLASTICS
308	FOSTER-MILLER	67420	0	0	0	85	I	AF	TRANS-LAMINAR REINFORCEMENT OF ORGANIC MATRIX
427	FOSTER-MILLER	449945	0	0	0	85	II	AF	TRANS-LAMINAR REINFORCEMENT OF ORGANIC MATRIX
441	FOSTER-MILLER	493539	0	0	0	85	II	AF	MIRCRO COMPOSITE PROCESSING
642	FOSTER-MILLER	0	64603	0	0	86	I	N	Z-DIRECTION REINFORCEMENT FOR COMPOSITES
715	FOSTER-MILLER	0	32796	32796	0	86	I	SDIO	NET SHAPE TUBLAR STRUCTURE FROM POLYMERS
798	FOSTER-MILLER	120999	120999	0	0	86	II	N	Z-DIRECTION REINFORCEMENT FOR COMPOSITES
969	FOSTER-MILLER	0	0	0	67320	87	I	AF	NON-METALLIC GUN BARRELS
1051	FOSTER-MILLER	0	0	74316	0	87	I	SDIO	DAMPED COMPOSITES
920	GENERAL SCIENCES	0	49050	0	0	87	I	AF	LIQUID METAL FILM FOR C-C COMPOSITE
375	GROSS T.A.O.	0	49724	0	0	85	I	N	EDDY CURRENT INSP. OF GRAPHITE-EPOXY COMPOSITE
453	GROSS T.A.O.	0	408423	0	0	85	II	N	EDDY CURRENT INSP. OF GRAPHITE-EPOXY COMPOSITES
31	IMI-TECH	47776	0	0	0	83	I	AF	LIGHT, STRONG FIBER REINFORCED POLYIMIDE FOAM COMP.
619	INTERMAGNETICS GENERAL	0	0	50000	0	86	I	DOE	FILAMENT INSTABILITY IN MULTIFILAMENTARY COMPOSITE
1105	INTERMAGNETICS GENERAL	0	0	49959	0	87	I	SDIO	REFRACTORY MATERIALS FOR COMPLING MEDIUM
996	J&D SCIENTIFIC	0	0	49996	0	87	I	N	MICROSCOPY OF METAL MATRIX COMPOSITES
1150	J&D SCIENTIFIC	0	0	494282	0	87	II	N	STUDY CORROSION OF ALUMINUM MATRIX COMPOSITES
1155	J&D SCIENTIFIC	0	0	488748	0	87	II	N	MICROSCOPY OF METAL MATRIX COMPOSITES
1104	KEMP	0	0	49500	0	87	I	SDIO	METAL OPTIC COMPOSITES FOR THERMIONIC CONVERSION
932	KETRON	49937	0	0	0	87	I	AF	COMPOSITE MATERIALS FOR MANIKIN SKELETONS
167	KJS	0	0	48608	0	84	I	DOE	PERMANENT MAGNETICS FOR METAL-MATRIX
126	KOFORD ENGINEERING	39387	0	0	0	84	I	A	MFG OF FIBER REINFORCED ORGANIC MATRIX COMPOSITES
834	KSE	49958	0	0	0	87	I	A	THERMOPLASTIC ELASTOMER BINDER
982	MACOMOLECULAR MTRL	0	50000	0	0	87	I	DARPA	MECH PROP OF GRAPHITE REINFORCED COMPOSITE
11	MATERIAL CONCEPTS	0	0	49683	0	83	I	A	AL MATRIX COMPOSITES
129	MATERIAL CONCEPTS	0	0	49401	0	84	I	A	LIQUID METAL INFILTRATION OF FIBERS
347	MATERIAL CONCEPTS	0	0	25000	25000	86	I	N	CERAMIC REINFORCED MMC
657	MATERIAL CONCEPTS	0	25000	25000	0	86	I	N	IMPROVED THERMAL & MACH PROPERTIES OF GRAPHITE COMPOSITES
811	MATERIAL CONCEPTS	0	0	250000	250000	86	II	N	CERAMIC REINFORCED MMC
131	MATERIAL SCIENCES	49257	0	0	0	84	I	A	TRI-AXIAL WOVEN STRUCTURES
142	MATERIAL SCIENCES	0	49268	0	0	84	I	AF	EVALUATION OF HIGH ENLOGATION CARBON FIBER COMPOSITES
151	MATERIAL SCIENCES	50000	0	0	0	84	I	AF	IMPACT DAMAGE OF COMPOSITES
206	MATERIAL SCIENCES	376990	0	0	0	84	II	A	MULTI-AXIALLY WOVEN COMPOSITE LAMINATE REINFORCEMENT
308	MATERIAL SCIENCES	0	0	49990	0	86	I	N	WHISKER REINFORCED METAL MATERIALS
649	MATERIAL SCIENCES	0	0	50000	0	86	I	N	MTRLS JOINED FOR THERMAL MIS-MATCHED COMPONENTS
655	MATERIAL SCIENCES	16600	16600	16600	0	86	I	N	IMPROVED THERMAL & MECH PROPERTIES OF COMPOSITES
658	MATERIAL SCIENCES	0	0	49860	0	86	I	N	FRACTURE TOUGHNESS OF MMC
1035	MATERIAL SCIENCES	12475	12475	12475	12475	87	I	N	MATRIX COMPOSITE MATERIAL EVALUATION
583	MATERIALS INNOVATION LAB	0	49581	0	0	86	I	AF	JOINTING METHODS FOR CARBON/CARBON STRUCTURES
768	MATERIALS INNOVATION LAB	0	510676	0	0	86	II	AF	BRAZING AND DIFFUSION WELDING CARBON-CARBON COMPOSITES

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	CONTRACTOR	ORGANIC MATRIX	CARBON-CARBON	METAL MATRIX	CERAMIC MATRIX	FY	PHASE	SERVICE	REMARKS
975	MATERIALS RELIABILITY	0	0	49459	0	86	I	N	METAL MATRIX FOR REINFORCED COMPOSITES
808	MATERIALS RELIABILITY	0	0	248899	0	86	II	N	MATRIX ALLOY FOR REINFORCED COMPOSITE
1018	MATERIALS RELIABILITY	0	0	24915	24915	87	I	N	REDUCE STRESS IN CERAMIC REINFORCED METAL MATRIX
594	MAXDEN	0	61389	0	0	86	I	DARPA	NEW PRE-PREPARATION OF CARBON-CARBON COMPOSITES
918	MAXDEN	64000	0	0	0	87	I	AF	DEV HIGH TEMP RIGID-ROD POLYMERS
717	MISSION RESEARCH	50013	0	0	0	86	I	SDIO	FIBER REINFORCED RESIN MATRIX
1006	MSI ELECTRONICS	0	49171	0	0	87	I	N	CONDUCTIVITY MEASUREMENT FOR GRAPHITE COMPOSITE
670	MSNW	0	0	48858	0	86	I	N	CORROSION MECHANISMS IN MMC
553	MTRL & ELECTROCHEM RESCH	0	0	0	62000	86	I	AF	CERAMIC MATRIX COMPOSITE FOR GUN RAIL
716	MTRL & ELECTROCHEM RESCH	0	0	0	50000	86	I	SDIO	CERAMIC COMPOSITES FOR STRUCTURES
772	MTRL & ELECTROCHEM RESCH	0	0	0	500000	86	II	AF	CERAMIC MATRIX COMPOSITE FOR GUN RAIL
966	MTRL & ELECTROCHEM RSCH	0	0	0	45584	87	I	AF	CERAMIC LINED GUN BARRELS
686	NEVADA ENGR & TECH	0	0	49743	0	86	I	N	BEHAVIOR OF MMC AT CRYOGENIC TEMPERATURES
807	NEVADA ENGR & TECH	0	0	453418	0	86	II	N	BEHAVIOR OF MMC AT CRYOGENIC TEMPERATURES
377	NIAMER, CORROSION CONSULT	0	0	49900	0	85	I	N	CORROSION OF METAL MATRIX COMPOSITES
631	NUCLEAR & AEROSPACE MTR	0	49283	0	0	86	I	DOE	CARBON-CARBON COMPOSITES
152	OWA COMPOSITE SPECIALTY	0	0	49779	0	84	I	AF	HI-TEMP METAL MATRIX COMPOSITES
287	PDA ENGINEERING	0	49543	0	0	85	I	AF	CHARACTERIZING CARBON-CARBON COMPOSITES
410	PDA ENGINEERING	426841	0	0	0	85	II	A	PLASMA TREATMENT & KEVLAR/EPOXY COMPOSITES
428	PDA ENGINEERING	0	723745	0	0	85	II	AF	CHARACTERIZING CARBON-CARBON COMPOSITES
543	PDA ENGINEERING	23627	0	23627	0	86	I	AF	TOMOGRAPHY FOR DENSITY OF RESIN
550	PDA ENGINEERING	0	48197	0	0	86	I	AF	O2 PROTECTION FOR CARBON-CARBON COMPOSITE
588	PDA ENGINEERING	0	47945	0	0	86	I	AF	COMPOSITE FASTENERS FOR CARBON/CARBON STRUCTURES
611	PDA ENGINEERING	0	0	49977	0	86	I	DOE	COPPER-EPOXY COMPOSITES
831	PDA ENGINEERING	49998	0	0	0	87	I	A	COMPOSITE FLYWHEEL STORAGE DEVICES
917	PDA ENGINEERING	0	49596	0	0	87	I	AF	ELECTRO-MAGNETIC HEATING TECHNIQUE
832	POLYFORM	48478	0	0	0	87	I	A	INJECTION MOLDED PALLET
555	PPL	0	0	48461	0	86	I	AF	HIGH TEMP METAL-PLASTIC COMPOSITES FOR SEALING MTRLS
916	PRESTIGIOUS TECH SERVICES	0	49820	0	0	87	I	AF	AEROSTRUCTURAL COMPOSITES
970	PROGRAMMED COMPOSITES	24950	24950	0	0	87	I	DARPA	PROCESSING ADV COMPOSITES
1141	PROGRAMMED COMPOSITES	265465	265465	0	0	87	II	DARPA	PROCESSING ADV COMPOSITES
305	QUANTUM COMPOSITES	49928	0	0	0	85	I	AF	COMPOSITE REPAIR PREPREP
587	RADIATION MONITORING	0	71456	0	0	86	I	AF	NDE DETERMINATION OF PRESIN IN GRAPHITE COMPOSITES
995	RAYMOND LAB	0	0	49986	0	87	I	N	PHYSICS OF METAL MATRIX COMPOSITES
1013	REFRACTORY COMPOSITES	0	0	0	38475	87	I	N	CERAMIC COMPOSITES FOR LEADING EDGE STRUCTURE
1034	REFRACTORY COMPOSITES	0	24957	0	24957	87	I	N	INTEGRATED CERAMIC MATRIX PC BOARDS
653	RESEARCH OPPORTUNITIES	12250	12250	12250	12250	86	I	N	COMPOSITES FOR MISSILE STRUCTURE
1033	RESEARCH OPPORTUNITIES	12495	12495	12495	12495	87	I	N	EVALUATE COMPOSITE MTRL FOR ELECTRONIC DEVICES
1016	RESEARCH OPPORTUNITIES	0	0	49980	0	87	I	N	GRAPHITE REINFORCED MAGNESIUM COMPOSITE
480	SIMULA	12375	12375	12375	12375	86	I	A	USE OF COMPOSITES ON PRIMARY STRUCTURES
928	SIMULA	50000	0	0	0	87	I	AF	COMPOSITE MATERIALS FOR MANIKIN SKELETONS
140	SPARTA	0	0	48622	0	84	I	AF	HI-TEMP METAL MATRIX COMPOSITES
279	SPARTA	0	0	73943	0	85	I	AF	DEV BARREL MTRL FOR ELECTROMAGNETIC GUN

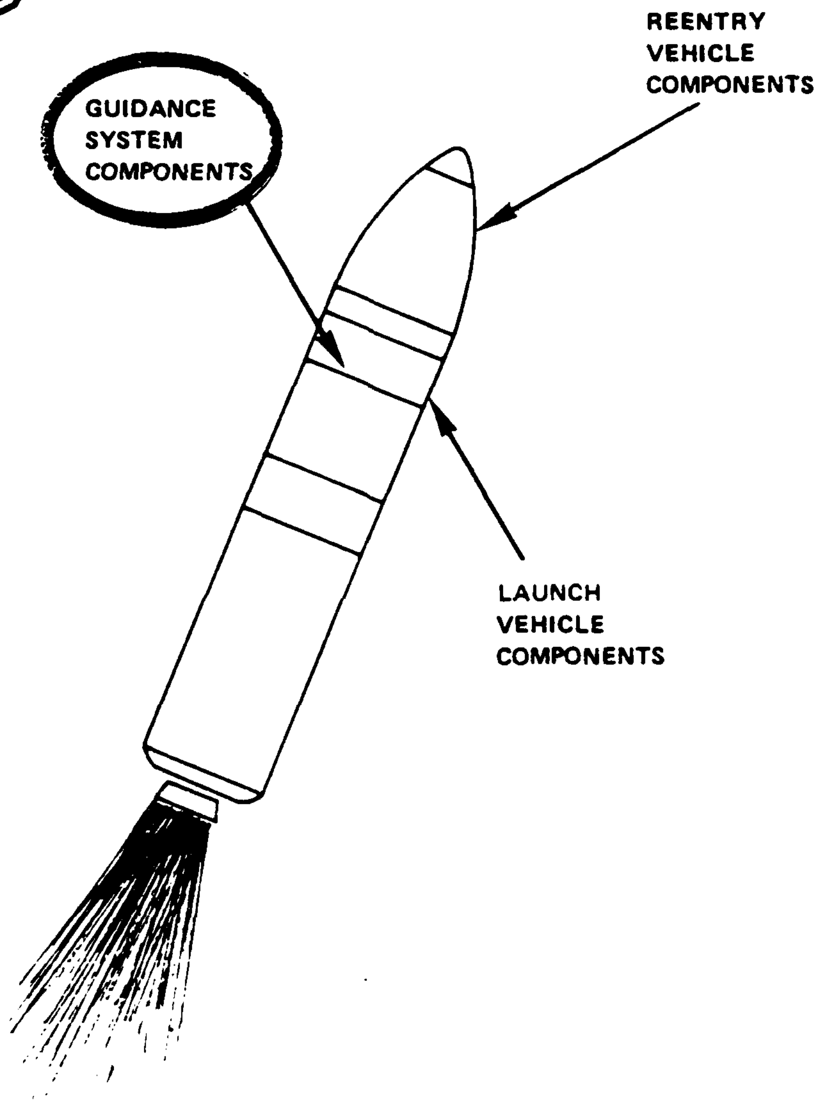
MR:kg-4
11/7/89

	CONTRACTOR	ORGANIC MATRIX	CARBON-CARBON	METAL MATRIX	CERAMIC MATRIX	FY	PHASE	SERVICE	REMARKS
688	SPARTA	0	16667	16667	16667	86	I	N	JOINTING OF THERMAL MIS-MATCHED COMPONENTS
821	SPARTA	0	532000	0	0	86	II	SDIO	METALLATED CARBON LASER SHIELD MATERIALS
884	SPARTA	0	0	24619	24619	87	I	A	METAL CERAMIC COMPOSITE ARMOR
973	SPARTA	0	83233	0	0	87	I	DARPA	OXIDATION PROTECTION FOR CARBON-CARBON COMPOSITES
1040	SPECIALITY PLASTIC	49876	0	0	0	87	I	N	DEV ADV COMPOSITE
1158	SPECIALITY PLASTICS	484165	0	0	0	87	II	N	DEVEL ADV COMPOSITE PIPE
721	SULLIVAN MINING	0	0	0	49806	86	I	SDIO	COATED-FIBER REINFORCED CERAMICS
56	SUPERCON	0	0	49966	0	83	I	DOE	COPPER-NIOBIUM COMPOSITE
342	SUPERCON	0	0	48961	0	85	I	DOE	SUPERCONDUCTING COMPOSITES
722	SYMETRIX	0	0	0	50000	86	I	SDIO	CHARACTERISTICS OF BORON NITRIDE ON CERAMIC
671	SYSTEM ENGINEERING	0	0	50506	0	86	I	N	FILAMENTARY METAL MATRIX COMPOSITE MATERIALS
568	TAYLOR S R	42243	0	0	0	86	I	AF	THERMOPLASTIC COMPOSITE PROCESSING
793	TECHNOLOGY DEVELOPMENT	0	369027	0	0	86	II	DNA	COMPONENTS MATERIAL FOR RV
449	TEXAS RESEARCH INST	327301	0	0	0	85	II	N	AIR FREE KEVLAR/URETHANE COMPOSITES
315	TEXTILE TECHNOLOGIES	0	33392	0	0	85	I	AF	FIBER-WEAVING OF TURBINE COMPOSITES COMPONENTS
1074	TEXTILE TECHNOLOGIES	0	66648	0	0	87	I	SDIO	GRAPHITE FIBER WOVEN COMPOSITES
429	ULTRAMET	0	499955	0	0	85	II	AF	OXIDATION PROTECTION FOR CARBON COMPOSITES
725	ULTRAMET	0	49992	0	0	86	I	SDIO	COATING FOR OXIDATION PROTECTION FOR GRAPHITE COMPOSITES
726	ULTRAMET	0	49994	0	0	86	I	SDIO	PROTECTIVE MATERIALS FOR CARBON COMPOSITES
741	ULTRAMET	125000	125000	125000	125000	86	II	A	COATED TUNGSTEN POWER FOR ADV ORDNANCE
33	UNIVERSAL ENERGY SYSTEMS	0	49168	0	0	83	I	AF	HIGH CONDUCTING CARBON COMPOSITES
176	WASTE ENERGY TECHNOLOGY	0	0	24960	24960	84	I	DOE	PRODUCE FERROUS METAL/CERAMIC COMPOSITES

MR:kg-5
11/7/89

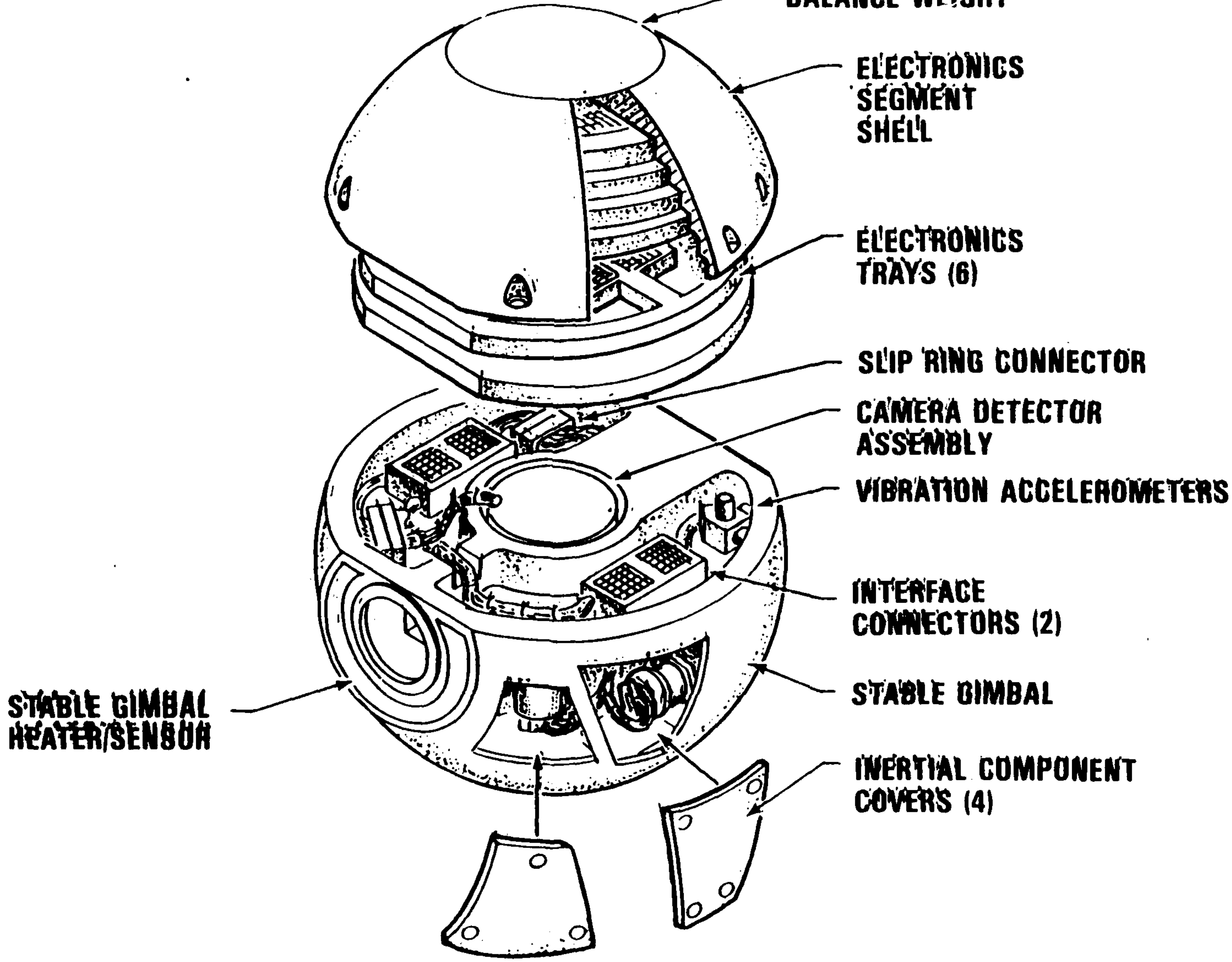
ADVANCED COMPOSITES FOR THE TRIDENT GUIDANCE SYSTEM AND LIGHTWEIGHT TORPEDO SHELLS

John V. Foltz (NSWC) gave a status summary on the work involved in the application of advanced composites for the Trident Guidance System. Work was also discussed relative to lightweight torpedo shells. Copies of the viewgraphs on both of these areas are appended.



STRATEGIC MISSILE MMC CANDIDATE APPLICATIONS

MK 6 STABLE GIMBAL ASSEMBLY



- High structural stiffness
- Low weight
- Dimensional stability
- Isotropic properties
- Good thermal match to S/M mounted components
- Thermally conductive
- Electrically conductive
- Machinable
- Availability/cost considerations

SUMMARY

TRIDENT II INTERTIAL MEASUREMENT UNIT GUIDANCE SYSTEM COMPONENTS

- STABLE MEMBER - A COMPREHENSIVE DATA BASE ON 30 v/o SiC/Al ESTABLISHED
- ELECTRONICS SHELL - A DECISION IS PENDING ON THE FUTURE USE OF 40 v/o SiC/Al
- INSTRUMENT COVERS - BASELINE MATERIAL IS 40 v/o SiC/Al

LIGHTWEIGHT TORPEDO SHELLS

- THREE MK 46 LIGHTWEIGHT TORPEDO SHORT FUEL TANKS BEING FABRICATED ON MANTECH SHEAR SPINNING PROGRAM
- WILL BE TRANSITIONED TO NOSC LIGHTWEIGHT TORPEDO FLEET FOR EVALUATION AS DEEPER DEPTH SUBSTITUTE FOR AA7075- T6 FUEL TANKS

POTENTIAL TRANSITIONS
MMC ARRAY PLATE FOR HEAVYWEIGHT TORPEDO

- THE ARRAYS HAVE BEEN ASSEMBLED BY THE TRANSDUCER PRIME CONTRACTOR - WESTINGHOUSE OCEAN SYSTEMS.
- UNDERGOING EVALUATION ON NUSC RESEARCH VEHICLES WITH IN WATER RUNS AT LAKE PEND OREILLE, ID, DABOB BAY, AND AUTEC.
- GOAL IS EQUAL PERFORMANCE WITH Ti BASELINE BUT WITH WEIGHT SAVINGS.
- TARGETED PRODUCTION VEHICLE IS Mk 48 ADCAP WITH SCEPS PROPULSION SYSTEM. SERIOUS WEIGHT PROBLEMS.

POTENTIAL TRANSITIONS
MMC ARRAY PLATE FOR HEAVYWEIGHT TORPEDO

- TOTAL COST TO BLOCK PROGRAM TO DATE IS APPROXIMATELY 500K, FOR MATERIALS, ASSEMBLED ARRAYS AND TECHNICAL SUPPORT AT NUSC. COSTS HIGHLY LEVERAGED IN BLOCKS FAVOR BY FREE USE OF RESEARCH VEHICLES FROM BRITAIN (LAKE PEND OREILLE) AND NUSC.

- POTENTIAL ONE PIECE NOSE/ARRAY PLATE DESIGN BEING DEVELOPED FOR NAVY MANTECH SHEAR SPINNING PROGRAM. IT SUCCESSFUL, THREE ONE PIECE ADCAP PARTS WILL BE SUPPLIED TO NUSC FOR EVALUATION.

- IOC DATE FOR CCAPS MOD OF Mk 48 ADCAP IN MID-NINETIES. SUNDSTRAND IS PRIME CONTRACTOR.

OVERALL PROGRAM MGM'T, ACQUISITION → PMS 402 CRYSTAL CITY (NAVSEA)

TECHNICAL AGENT FOR PMS 402 → NUSC, NEWPORT, R.I.

PRIME CONTRACTOR → HUGHES, FULLERTON, CA.

SUB-CON FOR TORPEDO ARRAY → WESTINGHOUSE ELECTRIC, ANNAPOLIS, MD.

PRIME CONTRACTOR CCAPS → SUNDSTRAND, ROCKFORT, IL.

THE METAL MATRIX QUESTION

Dr. Michael Rigdon of IDA presented a brief discussion of the status of metal matrix composite commercialization. He concluded there is no commercial market at the present and that MMC suppliers (particularly the continuous fiber MMCs) are primarily in the R&D business. Mention was made of the FMI "Technology Sustaining Proposal" that had been presented to SDIO and possibly others; the proposal implies that FMI might have to abandon the MMC business unless they obtain DoD support. Dr. Rigdon also posed the question of whether or not DoD needs these producers and outlined some options for keeping them around. Dr. Rigdon concluded by stating that the best option may be to help these small producers develop a commercial product that might not be of immediate interest to DoD. Subsequent discussion did not result in any consensus on what, if anything, should be done.

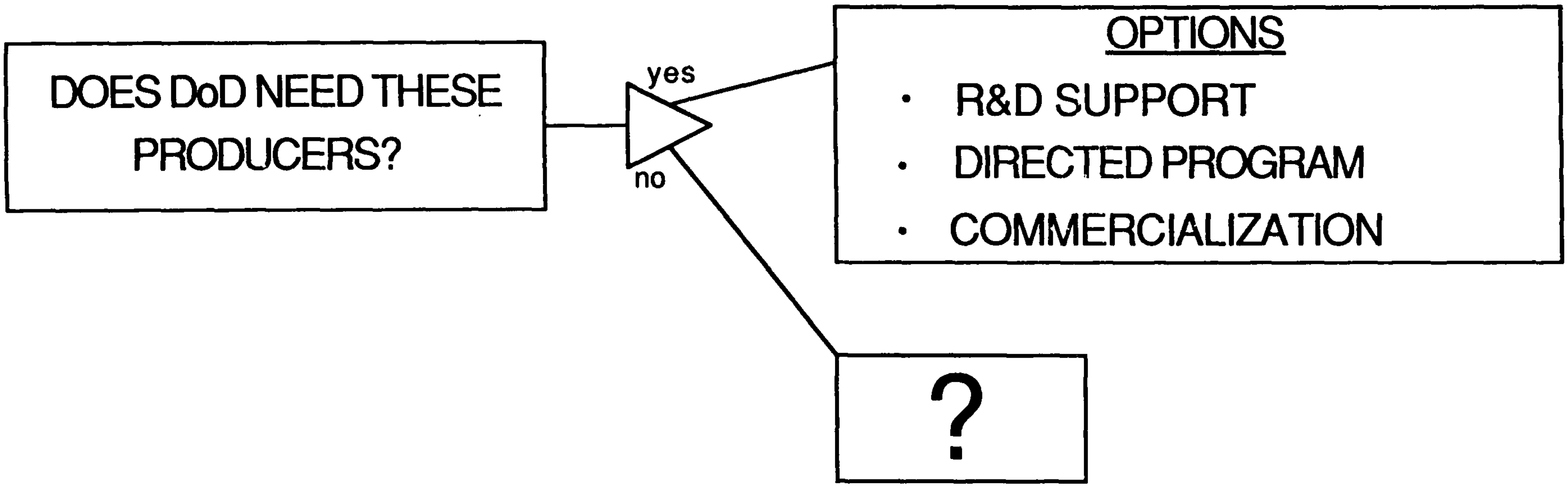
MMC STATUS

PARTICULATE REINFORCED	- TITLE III - LARGE AIRCRAFT STRUCTURES (R&D) - GUIDANCE PARTS (DoD) - NO COMMERCIAL MARKET
CONTINUOUS FIBER	- NUMEROUS SBIRs - NO COMMERCIAL MARKET

TRADITIONAL SUPPLIERS ARE IN THE R&D BUSINESS

MAR/dls:2
9/20/89

METAL MATRIX QUESTION



MAR/dls:5
9/20/89

SECTION C

CONCLUSIONS AND ACTION ITEMS

SECTION C

CONCLUSIONS AND ACTION ITEMS

A. CONCLUSIONS

It was agreed in principle by the meeting attendees that:

- While meetings such as the 5-6 October 1989 meeting are useful as a forum for MMC discussions and the interchange of information, it is unnecessary to hold these convocations more than once a year.
- MMC Technology Conferences (e.g., the Monterey Conference) have dwindled significantly in attendance. Because of this lack of interest and the fact that the conferences are relatively expensive to convene, it was agreed that the monies being spent to hold such conferences be used for other purposes.

B. ACTION ITEMS

The following items were deemed necessary for appropriate action:

- At the next MMC meeting (1990--specific month and day to be determined) an ITAR briefing will be given by a member of the U.S. Department of State. Also, since the consortium approach appears to be possible to employ in development programs, it may be advisable to invite an individual from the U.S. Department of Commerce to speak at the next meeting on the problems that may be involved in this approach.
- Frank Traceski (Defense Quality and Standardization Office) and Bill Johnson (Title III office) are to work together to include MIL-M-46196 (SiC/Al) in the TITLE III Procurement.
- Program Managers are to keep in contact with Bill McNamara (Kaman-Tempo) regarding an MMC data base format that can be incorporated into their CDRLs.

ANNEX

FA2 AND FA5 METAL MATRIX COMPOSITE DEVELOPMENTS

FA2 and FA5

METAL MATRIX COMPOSITE DEVELOPMENTS

DOD MMC STEERING GROUP
5 OCT 1989

A. GUNDERSON
WRDC/MLLN

NEW TITANIUM DIRECTIONS

LAST YEAR

FA2

ADV TITANIUM-BASE MATERIALS DEVELOPMENT

- MONOLITHIC ALUMINIDES
- TITANIUM ALUMINIDE COMPOSITES

FA5

MECHANICAL BEHAVIOR & LIFE PREDICTION OF ADVANCED TITANIUM ALLOYS & METAL-MATRIX COMPOSITES

THIS YEAR

FA2

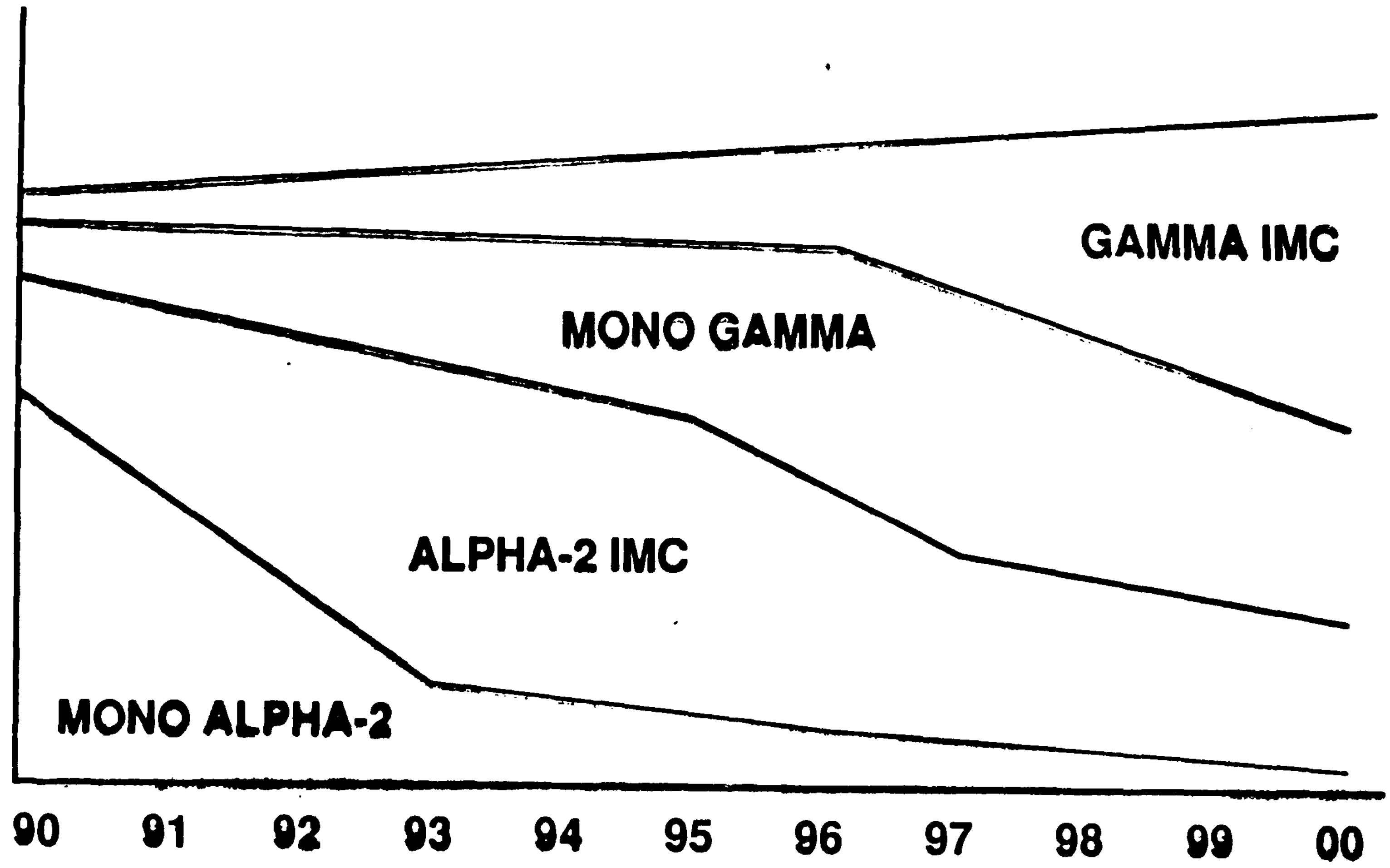
MONOLITHIC GAMMA TITANIUM ALUMINIDES

GAMMA TITANIUM ALUMINIDE INTERMETALLIC MATRIX COMPOSITES

ALPHA-2 TITANIUM ALUMINIDE INTERMETALLIC MATRIX COMPOSITES

FA5

FUTURE DIRECTIONS



USEFUL TEMPERATURE RANGES

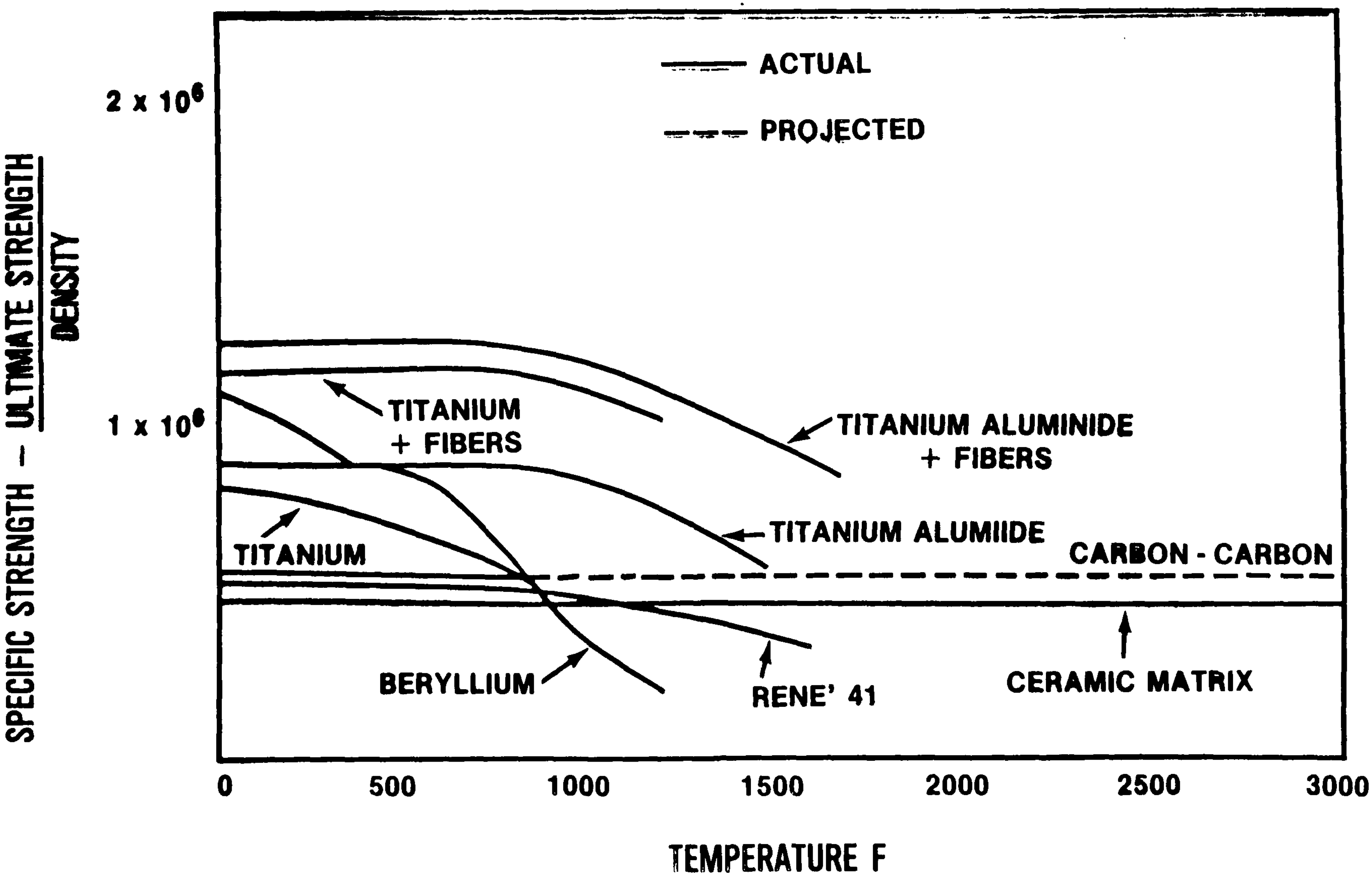
CONVENTIONAL TITANIUM	< 1300°F
TITANIUM ALLOY MMC	1300-1450°F
ALPHA-2 Ti ALUMINIDE	< 1300°F
ALPHA-2 Ti ALUMINIDE MMC	1300-1450°F
GAMMA Ti ALUMINIDE	1450-1600°F
GAMMA Ti ALUMINIDE MMC	1600-1800°F

TITANIUM ALUMINIDES

	TYPICAL Ti ALLOY	Ti_3Al	TiAl	SUPERALLOYS
DENSITY	5.3	4.1	3.75	8-9
MODULUS (PSI)	16×10^6	22×10^6	25.5×10^6	30×10^6
MAXIMUM TEMPERATURE				
• CREEP	800°F	1200°F	1600°F	1800°F
• OXIDATION	1100°F	1200°F	1800°F	1800°F

- POTENTIAL FOR LOWER COST
- LOWER COMPONENT STRESSES
- CONSERVE CRITICAL MATERIALS (Co, Ni, Cr)
- NON-PYROPHORIC (TiAl)

SPECIFIC STRENGTH OF CANDIDATE MATERIALS

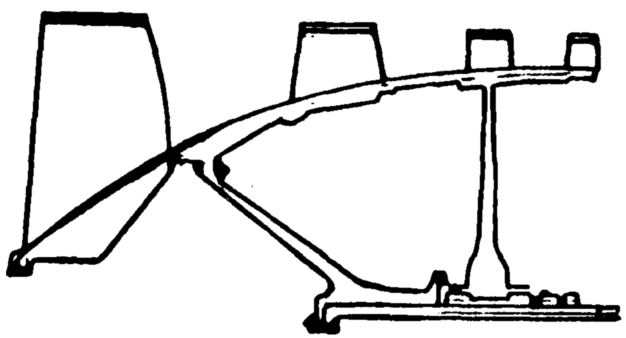


APPLICATIONS FOR TITANIUM ALUMINIDES

HIGH TEMPERATURE, LIGHTWEIGHT MATERIAL

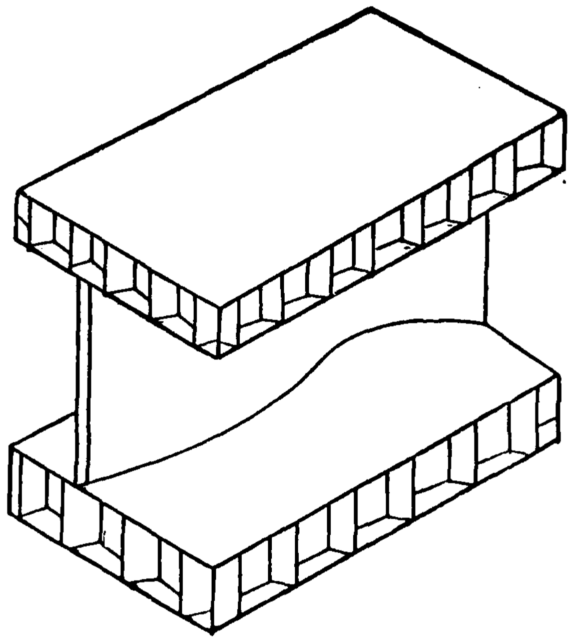
GAS TURBINE ENGINES

- STATIC COMPONENTS
  - STATORS/VANES
  - CASES
  - DUCTS
  - STRODS
- ROTATING COMPONENTS
  - BLADES
  - DISKS
  - ROTORS



HYPERSONIC VEHICLES

- HONEYCOMB PANEL



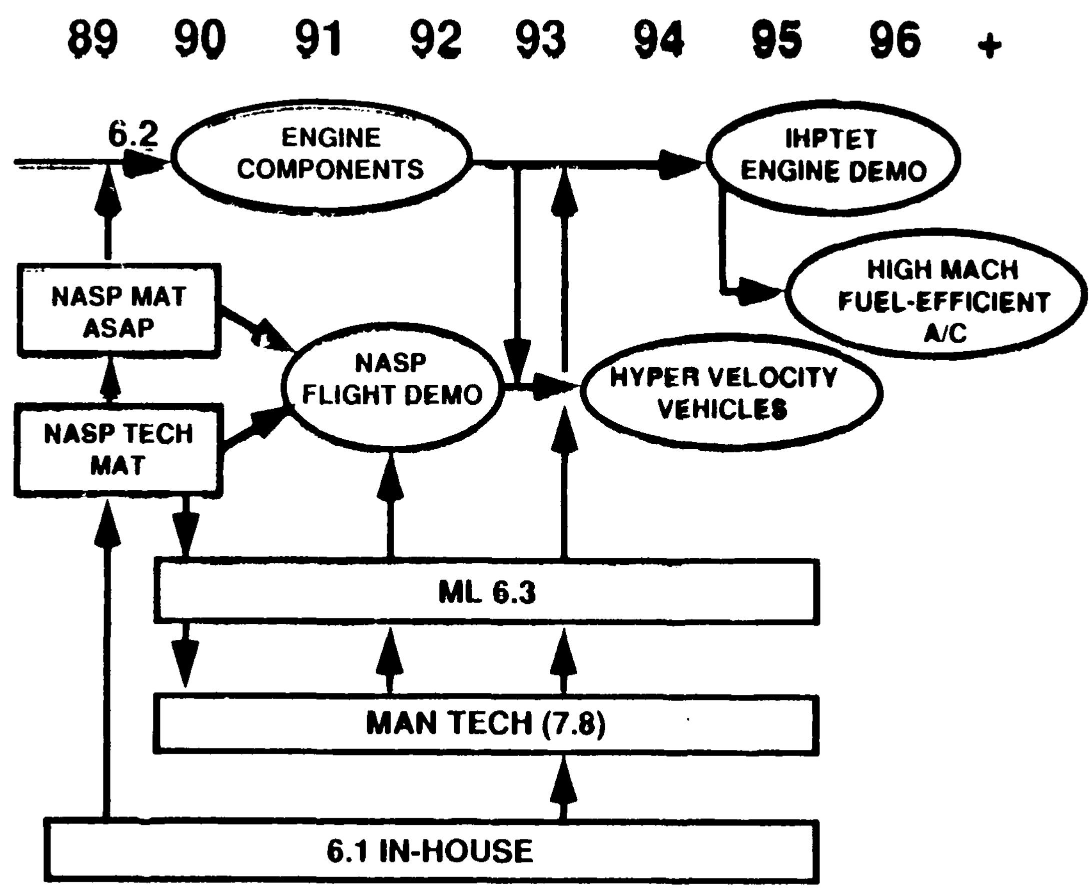
FY 90-91 NEW STARTS

- HIGH TEMPERATURE COATINGS FOR TITANIUM ALUMINIDES
- ALPHA-2 TITANIUM ALUMINIDE INTERMETALLIC-MATRIX COMPOSITE SYSTEM DESIGN

ROADMAP

KEY ACTIVITIES

- ALPHA-2 Ti ALUMINIDE
- ADV. INTERMETALLICS, REFRACTORY METALS & COMPOSITES
- CERAMIC MATRIX COMPOSITES
- ANALYTICAL & PHYSICAL PROCESS MODELING



FA5 - FUNDING BY DIRECTIONS

	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96
TI ALUM (ALPHA 2)	1114	1291	1213	1100	1060	900	800	800
ADV INTERMET & COMP	1027	747	840	960	1000	1100	1200	1200
CMC	1877	1625	1770	1800	1800	1860	1860	1860
PROC SCIENCE	FA9	1062	837	800	800	800	800	800
TOTAL (6.2)	4018	4725	4660	4660	4660	4660	4660	4660

FY 90 NEW START

TITLE: HIGH TEMPERATURE COATINGS FOR TITANIUM ALUMINIDES

OBJECTIVE: TO DEVELOP ENVIRONMENTAL PROTECTIVE COATINGS AND/OR SURFACE MODIFICATION TECHNIQUES FOR BOTH MONOLITHIC AND METAL-MATRIX COMPOSITE TITANIUM ALUMINIDES

APPROACH:
- SELECT ALPHA-2 AND GAMMA ALLOYS
- SCREEN EXISTING COATING SYSTEMS FOR BASELINE
- DEVELOP ADVANCED COATINGS/SURFACE MODIFICATIONS
  - IDENTIFY STABLE COATING/SURFACE CHEMISTRY
  - DEVELOP VIABLE COATING PROCESSES
- EVALUATE COATING PERFORMANCE IN OXIDATION, HOT SALT STRESS CORROSION,SULFIDATION
- EVALUATE COATING EFFECT ON MECHANICAL PROPERTIES IN REALISTIC ENVIRONMENTS

PAYOFF: DEVELOPMENT OF LIGHTWEIGHT TITANIUM ALUMINIDE GAS TURBINE ENGINE COMPONENTS FOR LONG LIFE, HIGH TEMPERATURE APPLICATIONS

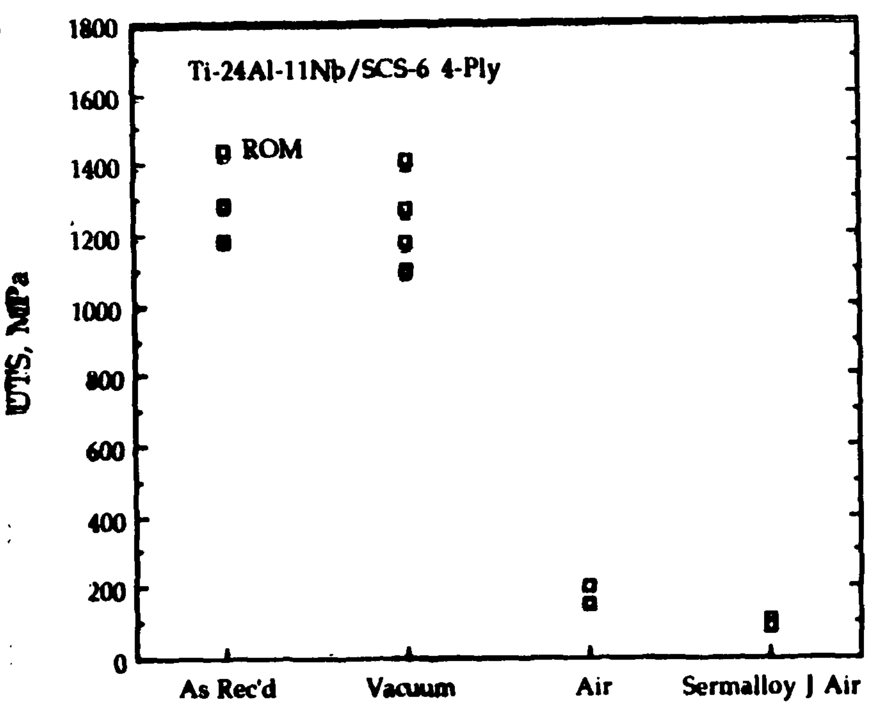
DURATION: 36 MONTHS

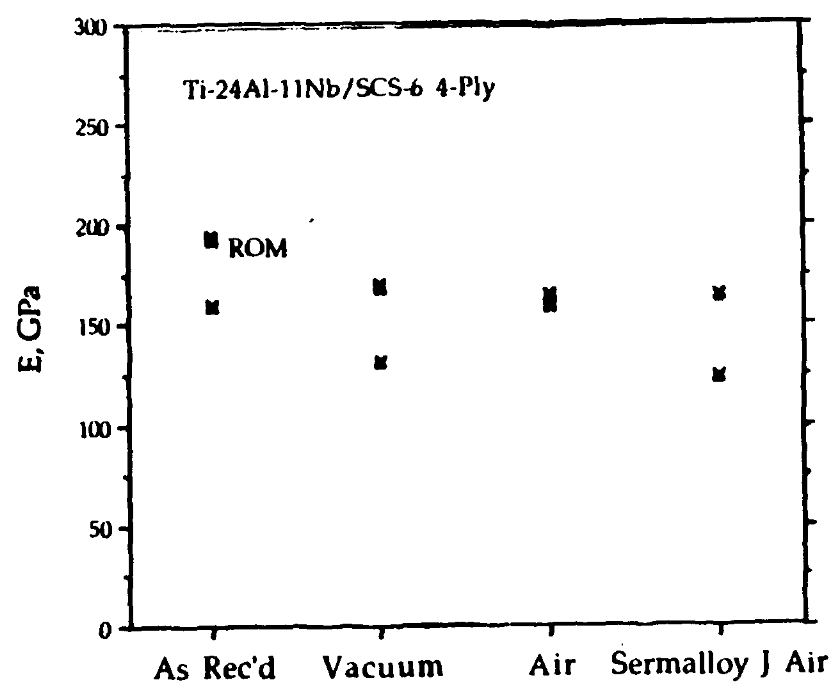
BUDGET ($K)	FY90	FY91	FY92	FY93	FY94	TOTAL
RM 6.2	100	485	365	200		1150

FORECAST II: PT-17 HIGH-TEMPERATURE MATERIALS
PT-03 HIGH-PERFORMANCE TURBINE ENGINE

IHPTET
NASP

THERMAL FATIGUE RESULTS





FY91 NEW START

FOCAL AREA: 5

TITLE: ALPHA-2 TITANIUM ALUMINIDE INTERMETALLIC-MATRIX COMPOSITE SYSTEM [illegible]

OBJECTIVE: [illegible]LOP THE FUNDAMENTAL SCIENCE OF CONTINUOUS-FIBER COMPOSITING WITH ALPHA-2 [illegible]IUM ALUMINIDE MATRICES. THIS INCLUDES AN UNDERSTANDING OF MATRIX ALLOY DEVELOPMENT SPECIFICALLY FOR INTERMETALLIC-MATRIX COMPOSITES, COMPOSITE PROCESSING AND FABRICATION, CHEMICAL COMPATIBILITY BETWEEN FIBER AND MATRIX, AND MECHANICAL COMPATIBILITY OF THE COMPOSITE SYSTEM.

APPROACH:
- DEVELOP NEW MATRIX ALLOY COMPOSITIONS SPECIFICALLY FOR COMPOSITES
- ACQUIRE NEW, ADVANCED FIBERS PRESENTLY IN DEVELOPMENT
- PROCESS AND FABRICATE COMPOSITE COUPONS
- CHARACTERIZE FIBER / MATRIX INTERFACE (CHEMICAL COMPATIBILITY, BOND STRENGTH)
  - AS CONSOLIDATED
  - AFTER THERMAL EXPOSURE
- INVESTIGATE VARIOUS PROCESSING TECHNIQUES (FOIL-FIBER-FOIL, NON-FOIL APPROACH)
- SELECT AND FABRICATE "BEST" COMPOSITE
  - CHARACTERIZE MECHANICAL PROPERTIES (CREEP, FATIGUE, FRACTURE)

PAYOFF: A FUNDAMENTAL UNDERSTANDING OF COMPOSITING WITH INTERMETALLIC MATRICES LEADING T[illegible] S[illegible]ABLE COMPOSITES FOR LONG LIFE, HIGH TEMPERATURE APPLICATIONS.

DURATION: 36 MONTHS

PERSONYEARS:

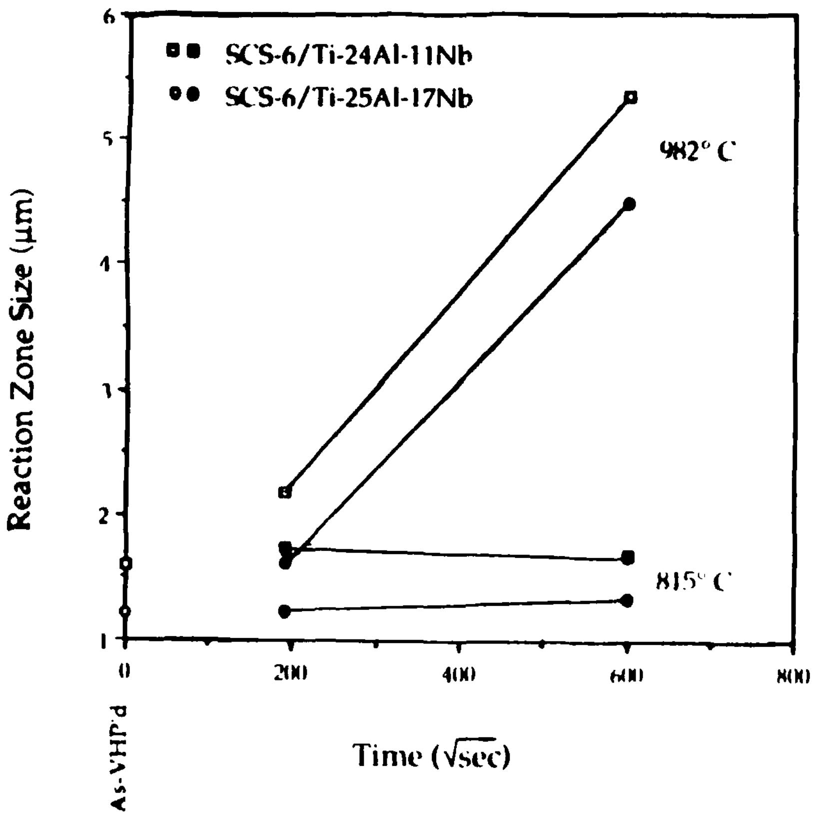
	FY90	FY91	FY92	FY93	FY94	TOTAL
6.2 (PY)		0.3	2.6	3.2	2.4	8.5

CONTACT: LT WILLIAM REVELOS, WRDC/MLLN, (513) 255-1366

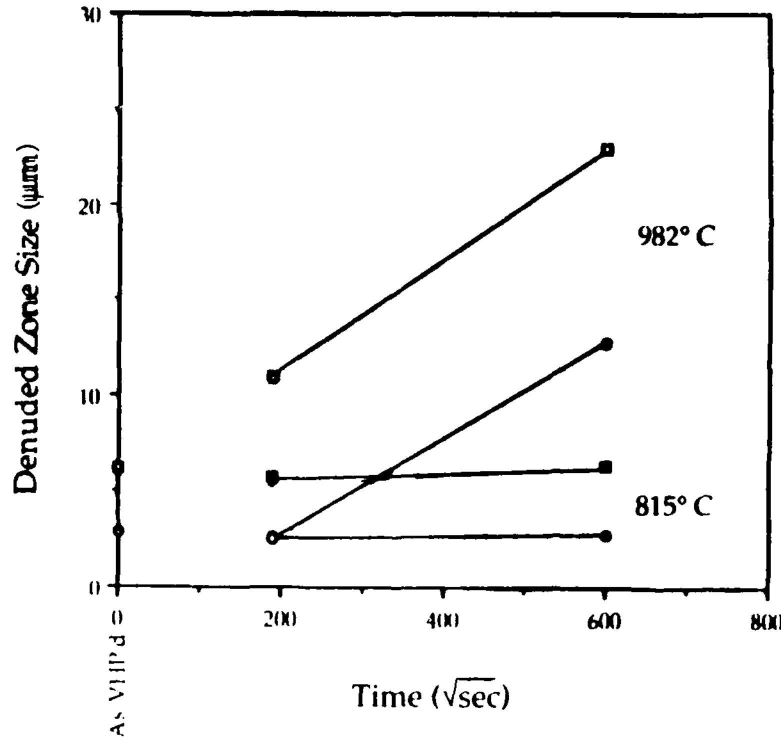
FORECAST II: PT-17 HIGH-TEMPERATURE MATERIALS IHPTET NASP
PT-03 HIGH-PERFORMANCE TURBINE ENGINE

Growth Kinetics

Reaction Zone



Beta Denuded Zone



DIRECTION: ALPHA-2 TITANIUM ALUMINIDE INTERMETALLIC-MATRIX COMPOSITES DATE: 3 APRIL 1989		GOAL: DEVELOPMENT OF THE FUNDAMENTAL SCIENCE OF CONTINUOUS FIBER COMPOSITING WITH INTERMETALLIC MATRICES, INCLUDING AN UNDERSTANDING OF MATRIX ALLOY DEVELOPMENT, COMPOSITE PROCESSING & FABRICATION, THE FIBER MATRIX INTERFACE, MICROMECHANICS, MECHANICAL BEHAVIOR, AND DAMAGE TOLERANT DESIGN										
		FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	ROADMAP ID	CONTRACTOR	POC
WUD #1: MECH PROP & CHAC O/S	6.1	[500]	[440]	[440]	[440]	[440]	[440]	[440]	[440]	2302P101	UDRI	NICHOLAS
	6.2	3	176	300	300	300	300	300	300	2302P102	UDRI	JIRA
	FA2	[187]	[130]									
WUD #1: VISIT SCIENTIST / NRC	6.1	[50]	[50]	[50]	[50]	[50]	[50]	[50]	[50]	2302P101	UDRI	NICHOLAS
TITANIUM MATRIX COMPOSITES (MDC)	NASP	[29.1M]	[22.1M]	[0.4M]							McDONNELL DOUG	SMITH
VERY HI TEMP TITANIUM	FA2	[135]	[80]							24180231	GENERAL ELECTRIC	BRODERICK
IMPROVED TOUGHNESS (PH I)	6.2	25								24200170	PRATT & WHITNEY	KERR
(PH II)	6.2	0								24200180	GENERAL ELECTRIC	KERR
MICRO/PROC EFF ON PROP OF Ti3AL	6.2	5	350	345	200					242001AB		WARD
	FA2		[50]									
ALPHA-2 Ti ALUM MMC SYS DESIGN	6.2			37	325	400	300					REVELOS
FAT & FRAC OF Ti3AL & COMP (PH I)	6.2	55								24200164	PRATT & WHITNEY	STUCKE
(PH II)	6.2	0								24200177	ALLISON	STUCKE
ADV Ti3AL MECH BEHAVIOR	SBIR	[250]	[196]							30055173	SYSTRAN	BALSONE
DAMAGE TOLERANCE IN Ti ALUM COMP	6.2	100	325	400	275					242001AC		LARSEN
	FA2		[100]									
TIME DEP BEHAVIOR IN Ti ALUM MMC	6.2					250	300	300	100			
ENVIRONMENTAL EFFECTS ON Ti ALUM	6.2	520	440	176						24200192	GARRETT	BALSONE
HI TEMP COATINGS FOR Ti ALUM	FA2		[100]	[485]	[365]	[200]				ML-90-2.1		BALSONE
BLADED IMC DRUM ROTOR	6.3			50	700	700	550					
PROC OF TITANIUM ALUMINIDES	6.2	361	[225]							24200173	ALLISON	OHARA
1400°F Ti ALUM MMC FEASIBILITY	NAVY	[100]									GARRETT	CULBERTSON
BONDING & JOINING OF Ti ALUM	NAVY		[50]	[150]	[235]	[200]						CULBERTSON
CONVENTIONAL Ti MMC	PO	[1941]	[2604]	[1009]							P&W / ALLISON	KOOP
TITANIUM ALUMINIDE MMC	PO	[1659]	[1513]	[328]	[323]						G.E. / ALLISON	KOOP
HIGH TEMPERATURE MAT'LS INITIATIVE	7.8		[684]	[4500]	[7000]	[6200]						
TOTALS	6.1	550	490	490	490	490	490	490	490			
	6.2	1114	1291	1213	1100	950	900	600	400			
[ ] OTHER FUNDS	6.3			50	700	700	550					
( ) OVERCEILING	BMR	-45		+45								

6.3 MAT TRANS

7.8 MANTECH

IHPTET

ADVANCED INTERMETALLIC METALS AND COMPOSITES

"APPROACH"

- TWO-PRONGED APPROACH:

  - INVESTIGATE NEW MONOLITHIC INTERMETALLIC COMPOUNDS WITH POTENTIAL FOR USE AS HIGH TEMPERATURE AEROSPACE MATERIALS.

  - DEVELOP INTERMETALLIC MATRIX COMPOSITES, WHERE REINFORCEMENTS ARE ADDED TO PROVIDE STRENGTH AT HIGH TEMPERATURE AND DAMAGE TOLERANCE BELOW THE DUCTILE-TO-BRITTLE TRANSITION TEMPERATURE OF THE MATRIX.

JOHN P. HENDERSON, Chief
Metals Behavior Branch
Metals and Ceramics Division

TECHNICAL AREA: PROPULSION MATERIALS (FA 5)

ROADMAP No. 52

DIRECTION:
ADVANCED INTERMETALLICS AND INTERMETALLIC COMPOSITES

GOAL:
DEVELOP ADVANCED INTERMETALLIC SYSTEMS FOR USE AT 2000-3000°F WITH A BALANCE OF MECHANICAL PROPERTIES WHICH ARE SUITABLE FOR ADVANCED TURBINE ENGINE COMPONENTS.

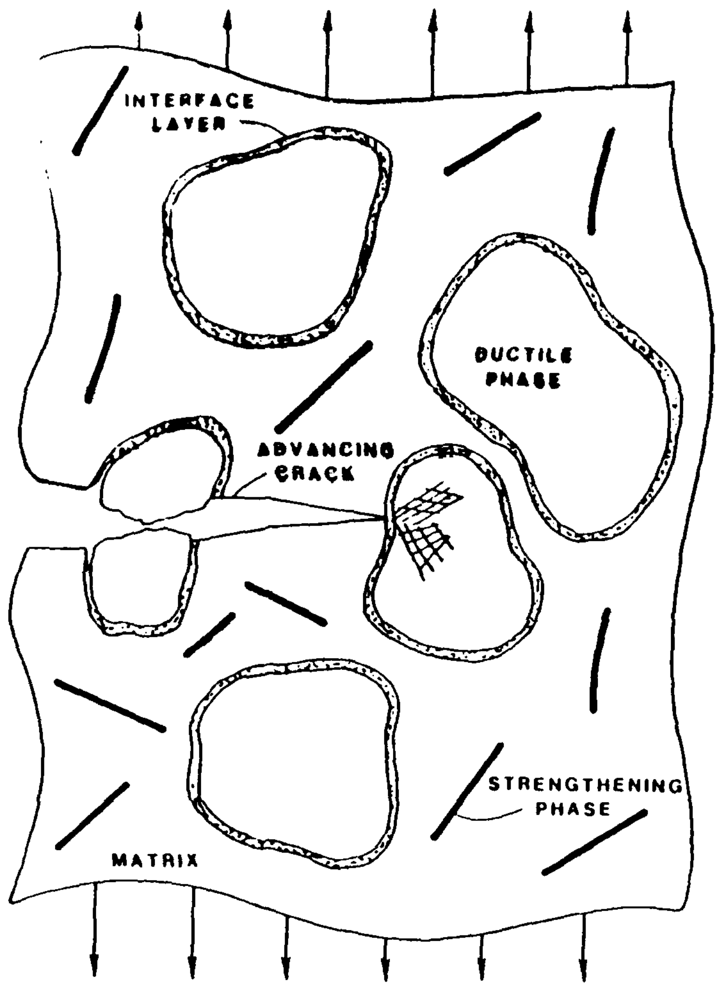
DATE: 3 APR 89

		FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	
IN-HOUSE RESEARCH										
GOVERNMENT MAN-YEARS	PY	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2306P106
ON-SITE RESEARCH	6.1	324	340	357	374	374	374	374	374	2306P109
ALLOY MODELING V.S.	6.1	70	70	75	75	75	80	80	80	
ON-SITE RESEARCH	6.2	141	155	180	200	200	200	200	200	
INTERMET. COMPOUNDS										
LTWT DISK ALLOY DEV.	6.2	191								24200176
ADV. INTERMET POTENTIAL	6.2	160	63							24200174
ADV. INTERMET POTENTIAL	6.2	135	59							242001AA
ADV. INTERMET MODELING	LDF	75								ILIR0206
CVD OF NB ALUMINIDES	SBIR	[200]	[230]							30055232
LDTA ALLOY DEV (DP-3)	6.2		(300)	(300)	(300)					
LDTA ALLOY DEV (PO)	6.2		[500]	[500]	[500]					
LDTA IPM DEMONSTRATION	6.3			[1000]	[700]	[800]				IHPTET
LDTA INTELLIGENT FABRICATION	7.8			[1000]	[800]	[800]	[400]			
LDTA ALLOY/PROCESS SCALE-UP	7.8					[2000]	[2000]	[2000]	[2000]	
INTERMETALLIC COMPOSITES										
TAILORED MICROSTRCTR BY PVD	LDF	175								ILIR0209
INTERMET COMP. FEASIBILTY	6.2	400	330	130						24200197
IN-SITU INTERMET COMPOSITES	6.2		140	400	400	360				
INTERMET COMP ALLOY DEV	6.2			130	360	400	400	100		
PROCESSING INTERMET COMP	6.2					40	400	400	400	IHPTET
LIFE PRED. OF INTERMET COMP	6.2						400	400	400	
INTERMET COMP COATINGS	6.2							100	200	
Nb ALLOY DEVELOPMENT										
NB ALLOY POWDER EXPLOR.	LDF	63								ILIR0202
TOTALS	LDF	313								
	6.1	394	410	432	449	449	454	454	454	
( ) OVERCEILING	6.2	1027	747	840	960	1000	1100	1200	1200	
[ ] FUNDED ELSEWHERE	6.2 OC		(300)	(300)	(300)					
	6.3			[1000]	[700]	[800]				
	7.8			[1000]	[800]	[2800]	[2400]	[2000]	[2000]	

MILESTONES/DECISION PTS

1. CONTINUE PVD DEVELOPMENT
2. INITIATE COMPOSITE PROCESSING
3. INITIATE COMPOSITE CHARACTERIZATION
4. DEFINE COMPOSITES FOR DEVELOPMENT
5. DEFINE COMPOSITION FOR XTC46-1
6. DEFINE PROCESSING TECHNIQUES FOR DEVLP

MULTI-CONSTITUENT ENGINEERED MATERIALS



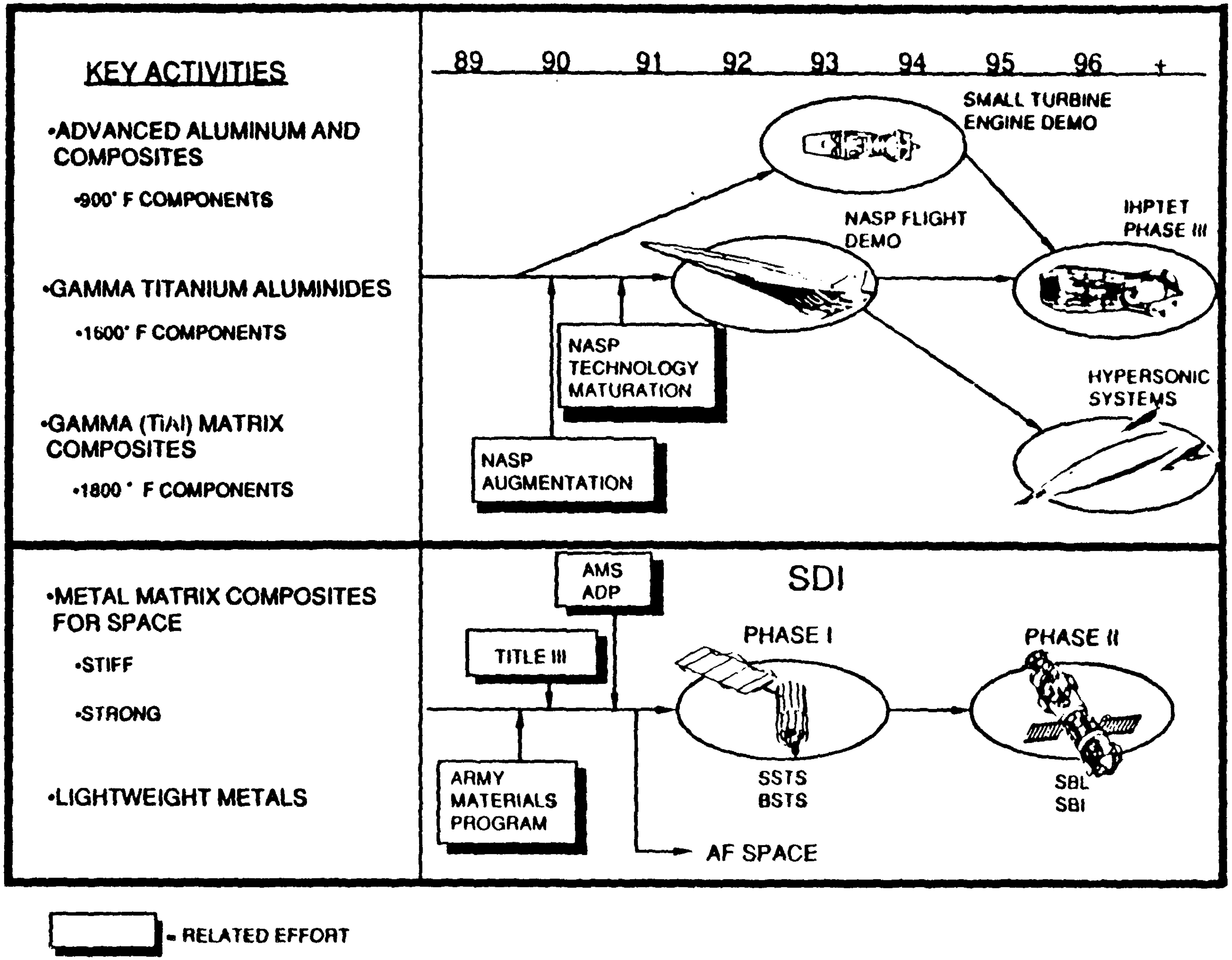
THE MICROSTRUCTURES OF FUTURE STRUCTURAL MATERIALS MUST BE DESIGNED FOR FRACTURE RESISTANCE AND HIGH TEMPERATURE STRENGTH

- **MONOLITHIC INTERMETALLICS**
- **REFRACTORY ALLOYS**
- **METALLIC/INTERMETALLIC MATRIX COMPOSITES**

FA-2

ADVANCED ALUMINUM ALLOYS AND COMPOSITES

METALLIC STRUCTURAL MATERIALS THRUST



INITIAL EFFORT FOR 900°F Al

CONTRACTOR: UNIVERSITY OF VIRGINIA

OBEJCTIVE: TO EXPLORE THE LIMITS OF ELEVATED TEMPERATURE PERFORMACE OF ALUMINUM BASE MATERIALS FOR AIRFRAME, MISSILE, AND PROPULSION APPLICATIONS

APPROACH: DISPERSION STRENGTHENED ALLOYS

- POWDER METALLURGY
- MECHANICAL ALLOYING

- ORDERED INTERMETALLIC COMPOUNDS
  - MECHANISTIC UNDERSTANDING OF DEFORMATION
  - MECHANISMS
  - ALTER MECHANISMS TO IMPROVE DUCTILITY

- METAL MATRIX COMPOSITES
  - ELEVATED TEMPERATURE ALUMINUM ALLOY MATRICES
  - DISCONTINUOUS REINFORCEMENTS

FY89 NEW START

FOCAL AREA: 2

TITLE: VERY HIGH TEMPERATURE (VHT) ALUMINUM ALLOY DEVELOPMENT

OBJECTIVE: TO DEVELOP Al-BASE MATERIALS FOR USE AT TEMPERATURES AS HIGH AS 900°F

APPROACH: EXPLOIT APPROACHES FROM THE VHT Al CONCEPTS PROGRAM AND OTHER APPROACHES: SOLICIT INDUSTRY INPUT BY USING PRDA

— PROCESS OPTIMIZATION
— INITIAL SCALE-UP
— MECHANICAL PROPERTY OPTIMIZATION

PAYOFF: LIGHTWEIGHT, LOW COST REPLACEMENT FOR TITANIUM

DURATION: 35 MONTHS

MANYEARS:

FY90	FY91	FY92	FY93	TOTAL
6.6	3.2	3.6	0.8	14.2

CONTACT: JOHN KLEEK, MLLS, 51313

FORECAST II: LPT-17, HIGH - TEMPERATURE MATERIALS

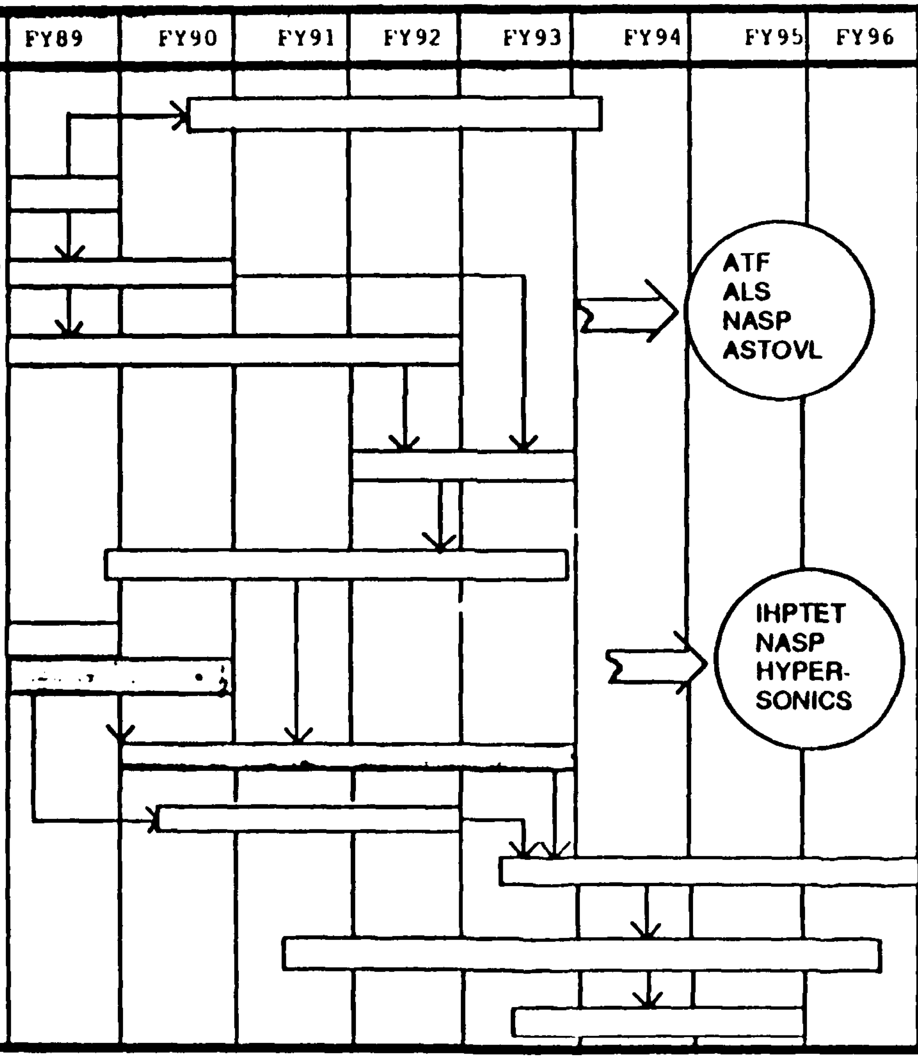
FOCAL AREA: METALLIC STRUCTURAL MATERIALS (FA2)

DIRECTION: 2-3
ADV ALUMINUM ALLOYS
AND COMPOSITES

GOAL:
DEVELOP AND VALIDATE TECHNOLOGY FOR ALUMINUM-BASE ALLOYS AND COMPOSITES CAPABLE OF SERVICE TEMPERATURES APPROACHING 900°F

DATE: 14 July 1989

		ROADMAP ID	POC
ETAL ROUND ROBIN	6.2		PHILLIPS
BILLET/PLATE/SHEET	7.8	MTP10659 ALCOA	POHLENZ
ETAL AIRCRAFT STRUCTURES	6.2F	LOCKHEED	BELLOTO
ETAP	6.3F	486U1002 LOCKHEED	FLORES
MT FOR ET AL FAB	7.8		GRIFFITH
DISCON REINFORCE Al (TITLE III)			ONDERCIN
VHT Al-BASE MATLS CON	6.2	24180230 UNIV OF VA	KIRCHOFF KLEEK
VHT AL ALLOY DEV	6.2		KLEEK
700°F AL ALLOYS	NADC		FRAZIER
VHT AL PROCESS OPT	6.2		KLEEK
VHT AL DEMO	6.3F		FLORES
MT FOR VHT ALUMINUM	7.8		GRIFFITH



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